Logistics Management Institute

The ASAC Air Carrier Investment Model (Revised)

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LMI

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Background

NASA's Role in Promoting Aviation Technology

The United States has long been the world's leader in aviation technology for civil and military aircraft. During the past several decades, U.S. firms have transformed this position of technological leadership into a thriving industry with large domestic and international sales of aircraft and related products. In 1992, sales of civil aircraft peaked at $39.9 billion, with exports of $24.3 billion. Exports of engines, parts, and related products totaled $12.4 billion in the same year. The comparable figures for 1994 were $26.3 billion, $18.8 billion, and $11.8 billion, respectively.

Despite its historic record of success, the difficult business environment of the past several years has stimulated concerns about whether the U.S. aeronautics industry will maintain its worldwide leadership position. Increased competition, both technological and financial, from European and other non-U.S. aircraft manufacturers has reduced the global market share of U.S. producers of large civil transport aircraft and cut the number of U.S. airframe manufacturers to only two. Order cancellations and stretch-outs of deliveries by airlines, forthcoming noise abatement requirements, and environmental concerns create additional challenges faced by U.S. producers and purchasers of aircraft.

The primary role of the National Aeronautics and Space Administration (NASA) in supporting civil aviation is to develop technologies that improve the overall performance of the integrated air transportation system, making air travel safer and more efficient, while contributing to the economic welfare of the United States. NASA conducts much of the basic and early applied research that creates the advanced technology introduced into the air transportation system. Through its technology research program, NASA aims to maintain and improve the leadership role in aviation technology and air transportation held by the United States for the past half century.

The principal NASA program supporting subsonic transportation is the Advanced Subsonic Technology (AST) program, managed by the Subsonic Transportation Division, Office of Aeronautics, NASA Headquarters. In cooperation with the Federal Aviation Administration and the U.S. aeronautics industry, the goal of the AST program is to develop high-payoff technologies that support the development of a safe, environmentally acceptable, and highly productive global air transportation system. NASA measures the long-term success of its AST program by how well it contributes to an increased market share for U.S.

civil aircraft and aircraft component producers and to the increased effectiveness and capacity of the national air transportation system.

NASA's Research Objective

To meet its objective of assisting the U.S. aviation industry with the technological challenges of the future, NASA must identify research areas that have the greatest potential for improving the operation of the air transportation system. Therefore, NASA seeks to develop the ability to evaluate the potential impact of various advanced technologies. By thoroughly understanding the economic impact of advanced aviation technologies and by evaluating how those new technologies would be used within the integrated aviation system, NASA aims to balance its aeronautical research program and help speed the introduction of high-leverage technologies.

Genesis of the Aviation System Analysis Capability

Technology Integration is the element of the AST program designed to ensure that the technologies NASA develops are timely and consistent with other developments in the aviation system. One of the objectives of the Technology Integration element is to develop an Aviation System Analysis Capability (ASAC). This analytical capability will give NASA and other organizations in the aviation community greater ability to evaluate the potential economic impacts of advanced technologies.

ASAC is envisioned primarily as a process for understanding and evaluating the impact of advanced aviation technologies on the U.S. economy. ASAC consists of a diverse collection of models, databases, analysts, and individuals from the public and private sectors brought together to work on issues of common interest to organizations within the aviation community. ASAC also will be a resource available to those same organizations to perform analyses; provide information; and assist scientists, engineers, analysts, and program managers in their daily work. ASAC will provide this assistance through information system resources, models, and analytical expertise, as well as through its role as a conductor and organizer of large-scale studies of the aviation system and advanced technologies. Figure 1 displays this concept.

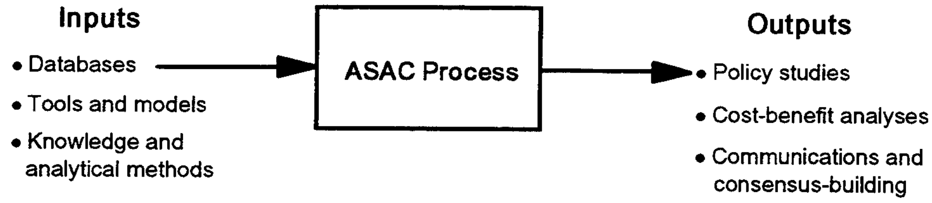

Figure 1.
The ASAC Process

Goals of the ASAC Project: Identifying and Evaluating Promising Technologies

The principal objective of ASAC is to develop credible evaluations of the economic and technological impact of advanced aviation technologies on the integrated aviation system. These evaluations would then be used to assist NASA program managers to select the most beneficial mix of technologies for NASA to invest in, both in broad areas, such as propulsion or navigation systems, and in more specific projects within the broader categories. Generally, engineering analyses of this kind require multidisciplinary expertise, possibly using several models of different components and technologies, giving consideration to multiple alternatives and outcomes. These types of analyses will be most effective if they use information and inputs from organizations and analysts from different parts of the aviation community. In this way, the studies will use the expertise of people around the United States and build acceptance from the start of the research effort.

In addition to the need for identifying broad directions for investments in technology, there is also a need to provide researchers at NASA and elsewhere with the ability to quickly evaluate the economic potential of alternative technologies and systems. By providing engineers better information on potential markets for technologies and data on how the current system works, ASAC will help NASA engineers incorporate the needs of their customers more easily into their routine work. These types of problems are most likely to involve investigations into specific technical designs of aircraft or subsystems that would be readily substituted for existing equipment now used by operators, without requiring significant changes to other aviation components. With such information, researchers could more easily evaluate the utility of alternative designs and obtain quick estimates of the value of their design concepts. Others using ASAC in this way would be analysts from industry, government, and universities.

Approach to Analyzing the Integrated Aviation System

The aviation technologies that are most likely to be useful are not necessarily the most technically advanced. Rather, it is critical that NASA and industry invest in the technologies that have the most promising payoffs. High-payoff technologies are those that clearly demonstrate a capacity for economically viable performance enhancements — from the perspective of those organizations that will purchase and operate the technologies.

Because new aviation technologies will be introduced into a complex system, it is critical that the potential impact of any proposed technology be analyzed from a systemwide perspective. Otherwise, the potential impact may be over- or underestimated due to the unexamined interdependencies with other elements of the aviation system. Figure 2 shows the components of the integrated aviation system.

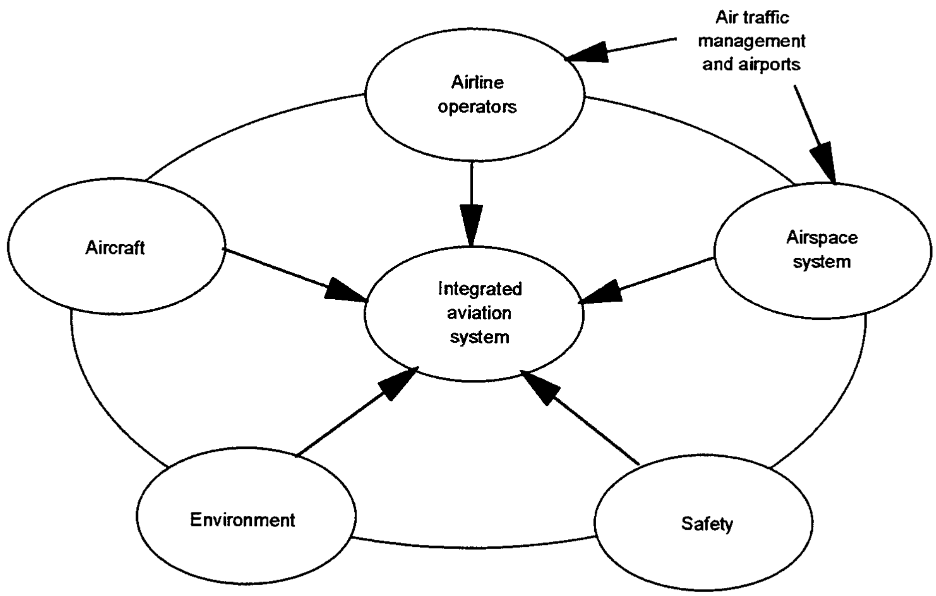

Figure 2.
Components of the Integrated Aviation System

Airline Economics and Investment Behavior Drive the ASAC

The ASAC differs from previous NASA modeling efforts in that the economic behavior of buyers and sellers in the air transportation and aviation industries is central to its conception. To link the economics of flight with the technology of flight, ASAC requires a parametrically based model that links airline operations and investments in aircraft with aircraft characteristics. That model also must provide a mechanism for incorporating air travel demand and profitability factors into the airlines' investment decisions. Finally, the model must be flexible and capable of being incorporated into a wide-ranging suite of economic and technical models that are envisioned for ASAC.

The remainder of this report describes a prototype air carrier investment model, developed by LMI, that meets these requirements.

Economic and Statistical Derivation of the ASAC Air Carrier Investment Model

Introduction

In creating the ASAC Air Carrier Investment Model, we had some specific goals in mind. A primary objective was to generate high-level estimates from

broad industry-wide supply and demand factors. We envisioned being able to forecast the demand for air travel under a variety of user-defined scenarios. From these air travel demand forecasts, we then could estimate the derived demand for the factors of production; most important, the number of aircraft in the fleets of U.S. passenger air carriers. We could also gauge the financial health of the airline industry as expressed in its operating profit margins.

To create the model, we first identified 85 key U.S. airports from which flights originate, and then developed airport-level demand models for passenger service provided by major air carriers. Furthermore, we linked the air carrier-specific demand schedules to an analysis of the carriers' technologies via their cost functions expressed in terms of the prices of the major inputs — labor, fuel, materials, and flight equipment. Flight equipment was modeled in an especially detailed way by incorporating some key operating characteristics of aircraft.[1]

From the cost functions, we generated derived demand schedules for the factors of production, in particular aircraft fleets. The derived demand schedules are functions of the price of the factor of production, prices of other factors, parameters that describe the aircraft and the network used by a carrier, and the level of passenger service supplied.

Because it is so capital-intensive, the airline industry must earn an operating profit margin of between 4 and 6 percent if it is going to maintain and expand its aircraft fleet. Accordingly, we added an operating profit margin constraint to the model. When this option is activated, passenger fare yields are adjusted up or down to ensure that the target operating profit margins are met.

Overview of the Basic Air Carrier Investment Model

As shown in Figure 3, the ASAC Air Carrier Investment Model starts with the factors affecting the demand for air passenger travel at the airline and airport levels. It then examines the determinants of airline cost functions and the resulting industry supply curve. The objective of both analyses is to obtain parametric estimates for the air travel demand and airline cost functions. These parametric estimates can then be combined with user-specified values of key supply and demand variables to generate industry-level forecasts of revenue passenger-miles (RPMs) flown,[2] number of aircraft in the fleets of U.S. passenger air carriers, and operating margins under various scenarios.

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[1] Acting under subcontract to LMI, Professor Robin Sickles of Rice University and Professor David Good of Indiana University generated the data sets and performed an econometric study of major U.S. airlines. They were assisted by Anthony Postert, a Ph.D. student at Rice University. See the bibliography for a listing of previously published studies by Sickles and Good.

[2] One revenue passenger (person receiving air transportation from the air carrier for which remuneration is received by the air carrier) transported one statute mile.

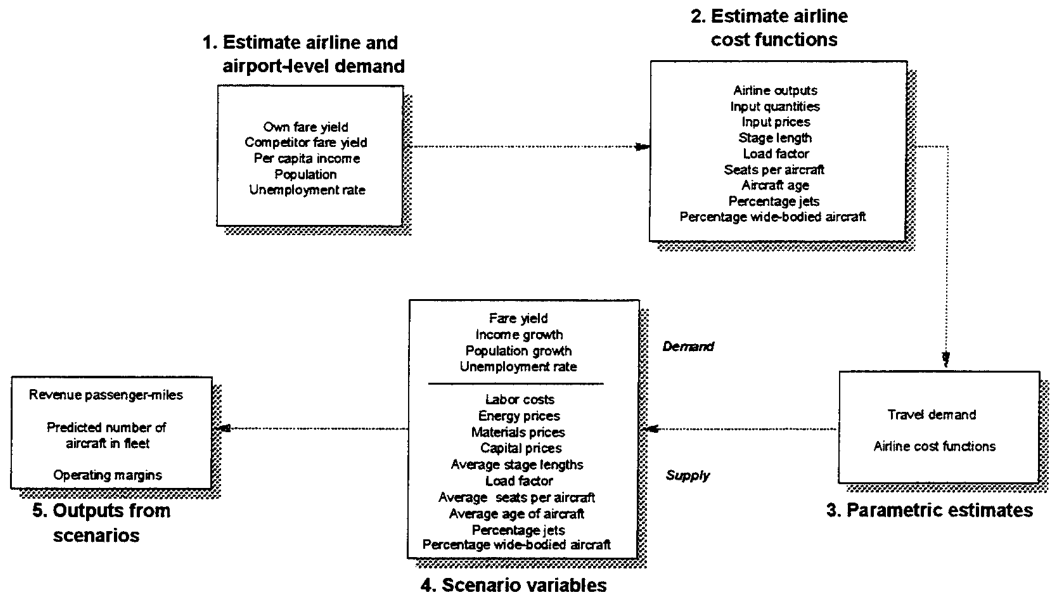

Figure 3.
Schematic of the ASAC Air Carrier Investment Model

Air Travel Demand

Our first analytical task was to develop a model of demand for an airline's passenger service. From a particular airport at origin *i*, carrier *j* will generate a certain level of passenger traffic. The U.S. Department of Transportation's (DOT's) Origin and Destination data record a 1 in 10 sample of all tickets; from these, the RPM service originating at a particular airport for a particular carrier was constructed. Demand for a carrier's service is driven by the carrier's passenger fare yield (measured by the average ticket price for flights originating at airport *i* divided by the average number of RPMs flown), its competitors' yields, and the size and economic prosperity of the market. We modeled the economic characteristics of the Standard Metropolitan Statistical Area (SMSA) surrounding the 85 airports in the study in terms of the area's population, per capita income, and unemployment rate. The period under consideration was from the first calendar quarter of 1979 through the last calendar quarter of 1992.

The demand function, in equation form, is

$$q_{t,i,j} = D_{t,i,j}(p_{t,i,j}, p_{t,i,c}, x_{t,i}) , \qquad \text{[Eq. 1]}$$

where $q_{t,i,j}$ is the scheduled demand (in RPMs) originating at time t from airport i for carrier j; $p_{t,i,j}$ is the average yield for service originating at time t from airport i

for carrier j; and $p_{t,i,c}$ is the average yield for the other carriers generating traffic at time t from airport i. The $x_{t,i}$ are the other demand characteristics at time t for airport i. Conventional treatments for firm and airport fixed effects were used. These effects capture those important characteristics of a particular city that are not easily measured, such as tourism effects. We used a log-log specification for Equation 1, so that the regression coefficients may be interpreted as elasticities.

Total demand for an air carrier's passenger service was then constructed by summing the airport-specific demand equations. In terms of Equation 1, the total demand for a carrier's service is given by

$$q_{t,j} = \sum_{i=1}^{ap} q_{t,i,j}, \qquad \text{[Eq. 2]}$$

where ap is the number of airports (85).

Table 1 shows the demand variables that were incorporated into the model. All of the explanatory variables were found to be statistically significant at the 95 percent level of confidence.[3]

Table 1.
Demand Variables

Variable	Name	Coefficient	T-ratio
Own fares	LNAVEOWN	– 1.165	– 46.00
Competitors' fares	LNAVEOTHER	0.095	1.83
Per capita income	LNPCI	1.334	8.33
Population	LNPOP	1.228	10.64
Unemployment rate	LNUNRATE	– 0.121	– 4.63

Note: Estimates of firm and airport variables are not reported.

Air Travel Supply

The second major component of our econometric study explains total carrier costs in terms of output quantities, factor prices, aircraft attributes, and network traits. The cost analysis was based mainly on observations from the DOT Form 41 data (discussed in more detail in Appendix A). The cost data follow 13 U.S. passenger air carriers with quarterly observations between the beginning of 1979 and the end of 1990. These firms are the set of former certificated

[3]The partial regression coefficients show the effects of changes in the independent variables (e.g., own fares, and competitors' fares) on the dependent variable (i.e., total demand for an air carrier's passenger service). The T-ratios show the degree to which the partial regression coefficients are statistically different from zero. For degrees of freedom over 30, a T-ratio of 1.96 provides 95 percent confidence that the partial regression coefficient is not zero.

carriers that existed throughout the study period and account for well over 95 percent of the domestic air traffic. From the Form 41 data, we generated a separate set of demand equations for each of the carrier's factors of production based on standard economic assumptions concerning the cost-minimizing behavior of a carrier. In turn, these demand equations permit examinations of the impact of factor price and factor productivity changes, fleet and network configurations, and aircraft operating characteristics.

Scheduled RPM traffic for carrier j at time t was constructed as the sum of originating traffic supplied by the carrier for all airports from which it offered flights. This was the first of the two outputs considered in the cost function below. The second was the level of nonscheduled RPM service. The two generic output categories at time t for carrier j are designated $y_{t,j,1}$ and $y_{t,j,2}$ for scheduled and nonscheduled RPM demand, respectively. The factors of production are labor, energy, materials, and capital. Factor prices are labeled w. In the model, capital refers to aircraft fleets only. Capital other than aircraft, such as ground structures and ground equipment, is included in the materials category. Omitting the time and firm subscripts, the transcendental logarithmic (translog) cost function is given by

$$\begin{aligned}\ln TC = \alpha_0 + \sum_{i=1}^{2} \alpha_i \ln y_i + \sum_{i\leq j}^{2}\sum_{j=1}^{2} \alpha_{ij} \ln y_i \ln y_j + \sum_{i=1}^{4} \beta_i \ln w_i \\ + \sum_{i\leq j}^{4}\sum_{j=1}^{4} \beta_{ij} \ln w_i \ln w_j + \sum_{i=1}^{4} \rho_i \, \mathit{aircraft\ attributes}_i \ln w_{capital} \\ + \sum_{i=1}^{2} \lambda_i \, \mathit{network\ traits}_i .\end{aligned} \qquad \text{[Eq. 3]}$$

Cost shares for labor, energy, and materials are given by

$$M_i = \beta_i + \sum_{j=1}^{4} \beta_{ij} \ln w_j . \qquad \text{[Eq. 4]}$$

The cost share for capital is

$$M_{capital} = \beta_{capital} + \sum_{j=1}^{4} \beta_{capital,j} \ln w_j + \sum_{j=1}^{4} \rho_j \, \mathit{aircraft\ attributes}_j . \qquad \text{[Eq. 5]}$$

The translog cost equation can be viewed roughly as a second-order approximation of the cost function dual to a generic production function. Symmetry and linear homogeneity in input prices are imposed on the cost function by the restrictions:

$$\alpha_{ij} = \alpha_{ji}, \forall i,j;\ \beta_{ij} = \beta_{ji}, \forall i,j;\ \Sigma_i \beta_i = 1;\ \Sigma_j \beta_{ij} = 0;\ \mathit{and}\ \Sigma_j \rho_j = 0.$$

Summary statistics based on the translog cost equation and its associated share equations are provided by the Morishima and Allen-Uzawa substitution elasticities.[4] Several measures of returns to scale can also be obtained from the parameter estimates.

Aircraft attributes are modeled from various characteristics of the aircraft fleet. A major component of airline productivity growth is measured by changes in these attributes over time. For example, all other things being equal, newer aircraft types are expected to be more productive than older types. The most significant contribution to productivity growth in the 1960s was the introduction of jet equipment. While this innovation was widely adopted, it was not universal for carriers throughout the data sample. Newer wing designs, improved avionics, and more fuel-efficient propulsion technologies also make flight equipment more productive. Once an aircraft design is certified, a large portion of the technological innovation becomes fixed for its productive life.

In an engineering sense, transportation industries tend to be characterized by increasing returns to equipment size. Fixed costs for fuel, pilots, terminal facilities, and even landing slots can be spread over more passengers. However, large aircraft size is not without potential diseconomies. As equipment size increases, it becomes more difficult to fine-tune air traffic scheduled capacity on a particular route. Because airline capacity (reflected by available seat-miles) is concentrated into fewer and fewer departures, quality of service also declines (the probability decreases that a flight is offered at the time a passenger desires it most). This raises particular difficulties in competitive markets where an airline's capacity must be adjusted in response to the behavior of rival carriers. Deregulation has accentuated this liability by virtually eliminating monopolies in domestic high-density air travel markets. On the other hand, deregulation has increased the total volume of traffic through more vigorous fare competition, somewhat attenuating this liability. In any event, the operating economies of increased equipment size must be traded off against limited flexibility.

Two attributes of the carrier's network are also included in the model: average stage length and passenger load factor. Stage length allows us to account for different ratios of costs due to ground-based resources compared with costs attributable to the actual stage length flown. Shorter flights use a higher proportion of ground-based systems per passenger-mile of output than do longer flights. Also, shorter flights tend to be more circuitously routed by air traffic control and spend a lower fraction of time at an efficient altitude than longer flights. Passenger load factor can be viewed as a control for capacity utilization and macroeconomic demand shocks. Many transportation studies also interpret it as a proxy for service quality. As load factors increase and the network becomes less resilient, the number and length of passenger flight delays generally increase as do the number of lost bags and ticketed passengers who are bumped. Inflight service levels also decline since the number of flight attendants is not generally adjusted upward as passenger load factor increases.

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[4] The Morishima and Allen-Uzawa substitution elasticities are measures of the degree to which the various factors of production may substitute for one another, holding factor prices and the level of production constant.

Estimates of the long-run cost function and summary statistics for various elasticities are provided in Table 2.

Table 2.
Supply Variables

Variable	Name	Coefficient	T-ratio
Labor price	LNLP	0.584	N/A
Labor price squared	LNLP^2	– 0.020	– 2.53
Labor × energy	LNLPEP	– 0.017	– 4.32
Labor × materials	LNLPMP	0.032	5.25
Labor × capital	LNLPKP	0.005	1.87
Energy price	LNEP	0.173	N/A
Energy price squared	LNEP^2	0.104	40.10
Energy × materials	LNEPMP	– 0.074	– 24.09
Energy × capital	LNEPKP	– 0.013	– 9.20
Materials price	LNMP	0.163	N/A
Materials price squared	LNMP^2	0.089	12.01
Materials × capital	LNMPKP	– 0.047	– 14.80
Capital price	LNKP	0.079	N/A
Capital price squared	LNKP^2	0.055	25.40
Scheduled demand	LNSQ	0.642	25.13
Scheduled demand squared	LNSQ^2	0.091	1.71
Nonscheduled demand	LNNQ	0.228	10.55
Nonscheduled demand squared	LNNQ^2	– 0.006	– 0.11
Scheduled × nonscheduled demand	LNSQNQ	– 0.023	– 0.50
Stage length	LNSL	– 0.220	– 4.81
Load factor	LNLF	– 0.511	– 7.68
Average seats	XLNAS	0.014	4.61
Average age	XLNAA	– 0.011	– 3.69
Percentage jets[a]	XXPJ	0.003	3.91
Percentage wide-bodied aircraft[a]	XXPWB	– 0.006	– 6.45

Note: Estimates of firm and quarterly dummy variables are not reported.

[a] All other variables are expressed as natural logarithms.

Using the Model

General Approach

The joint model of supply and demand for commercial passenger air service specified in our study and the inferences about the demand for airplanes that are imbedded in our econometric results allow us to simulate the effects of emerging airframe and engine technologies by modifying characteristics of the planes in service. We can also simulate the growth in total system demand for passenger service and for factor inputs such as the number of aircraft in the fleet.

We incorporated the estimated regression coefficients into a spreadsheet model. Details of the model and user instructions are found at Appendix B.

We follow several general steps when evaluating scenarios: First, we predict the change in RPMs based upon economic forecasts and the demand equation estimates. Next, we estimate airline revenues based upon forecast RPM growth and hypothesized changes in ticket prices. Then we estimate airline operating costs on the basis of forecasted RPM growth, changes in input prices, and changes in aircraft and network characteristics. We predict the aircraft inventory from airline operating costs, the capital share equation, and hypothesized changes in aircraft price and aircraft size. Finally, we compare forecasts from the ASAC Air Carrier Investment Model with predicted changes in RPMs, aircraft fleet, and operating margins from other published forecasts.

Forecasting Changes in Travel Demand, Airline Costs, and Aircraft Fleets

Travel Demand

To predict changes in travel demand, the model starts with actual airline output for the last two quarters of 1993 and the first two quarters of 1994 and changes it over time based on the estimated demand function coefficients and predicted changes in the explanatory variables. The equation for predicting annual changes in demand is

$$\%\Delta RPM = \sum_{i=1}^{5} \beta_i \, \%\Delta X_i , \qquad \text{[Eq. 6]}$$

where the β_i are the coefficients estimated from the econometric model and the X_i are the explanatory variables. Due to the logarithmic structure of the statistical model, the coefficients are interpreted as elasticities. For example, the coefficient of 1.334 on per capita income means that a 1 percent increase in per capita income raises the demand for air travel by 1.334 percent.

The annual percentage change in per capita income, population, and unemployment are parameters entered by the user. The baseline model uses

estimates of population growth published by the Bureau of Labor Statistics. Per capita income growth is not directly input into the model. Instead, the user provides estimates of the long-run annual growth rates in gross domestic product and population. The model then calculates the annual change in per capita income and uses it to generate the demand forecast.

Fare variables are treated in one of two possible ways. User-defined rates of change in fare yields can be input directly into the model, and their effects will be estimated immediately. The second mode of operation, as described later in the report, allows the user to set a series of profit rate constraints for each of the four, five-year intervals in the forecast period. The user then instructs the model to vary the fare yields until the profit rate constraints are met.

The econometric estimates of the demand function are based on quarterly traffic volume for each airline and airport in the sample. While it is possible to build the demand forecasts up from this highly detailed level, it would be time-consuming and probably add more inaccuracy to the final estimate. Instead, we use the actual scheduled and nonscheduled RPM data for the domestic and international routes of U.S. passenger airlines as the starting point, and grow demand at the rate indicated by Equation 6. This imposes the constraint that output grows at the same rate for each airline. While obviously inaccurate, this is not a significant bias in the model since our goal at this time is to forecast industry-wide demand, costs, and aircraft fleets. For long-run forecasts such as those generated by the model, it is immaterial whether the aggregate demand for air travel is satisfied by a particular carrier such as United Airlines or Delta Airlines.

For purposes of forecasting fares and for calculating industry travel demand, the own-fare and other-fare changes are assumed to be identical. Therefore, the overall price effect is the sum of the two coefficients. The net effect shows that air passenger travel is sensitive to price changes, but not unusually so. The model predicts that a 10 percent reduction in fares will increase RPMs by 10.7 percent. This implies that after holding other factors constant — such as population and income — changes in air fares will have virtually no effect on total revenues collected by the industry.

Airline Costs

Equation 3 describes the airline cost equation estimated for the model. As shown, total costs are a function of airline outputs, input prices, and aircraft and airline network attributes. Using the supply parameter estimates shown in Table 2, Equation 3 can easily be used to produce a time series of predicted

changes in airline costs. Using the log-log structure of the equation to our advantage, the following forecast equation is derived:

$$\begin{aligned}\%\Delta TC = &\sum_{i=1}^{2}\alpha_i\%\Delta y_i + \sum_{i\le j}^{2}\sum_{j=1}^{2}\alpha_{ij}\%\Delta y_i\%\Delta y_j + \sum_{i=1}^{4}\beta_i\%\Delta w_i \\ &+\sum_{i\le j}^{4}\sum_{j=1}^{4}\beta_{ij}\%\Delta w_i\%\Delta w_j + \sum_{i=1}^{4}\rho_i\ \%\Delta \mathit{aircraft\ attributes}_i\ \%\Delta w_{capital} \\ &+\sum_{i=1}^{2}\lambda_i\ \%\Delta \mathit{network\ traits}_i,\end{aligned} \qquad \text{[Eq. 7]}$$

where %Δ means annual percentage change in the variable.

In Equation 7, factor prices *w*, *aircraft attributes*, and *network traits* are user-defined variables in the ASAC Air Carrier Investment Model. Scheduled and nonscheduled output changes are estimated directly in the demand model forecasting component and then input into the cost functions. Therefore, changes in output cannot be made directly by the user.

As with the demand forecasts, total costs are projected forward from the baseline defined by the reported data. The model increases the costs at the rates predicted by the model, given output forecasts, input price changes, and changes in aircraft and network characteristics.

Aircraft Fleets

Estimating the aircraft fleet required to meet the forecasted travel demand is a somewhat more involved process. Four factors enter into the forecast of aircraft fleets:

- The changes in total airline costs
- The estimated share of aircraft costs in total costs
- The forecasted change in aircraft capital costs
- The growth in average aircraft size.

Changes in total airline costs were discussed in the previous section. Referring to Equation 5, the aircraft share of total costs is a function of input prices and aircraft attributes. As with the cost and demand forecasts, we update the capital share equation through the forecast period as a function of the rates of

change in the factor price and aircraft attribute parameters. The equation for changes in the capital cost share is

$$\Delta\ capital\ cost\ share = \sum_{j=1}^{4} \beta_{capital,j} \% \Delta w_j + \sum_{j=1}^{4} \rho_j \% \Delta aircraft\ attributes_j. \qquad \text{[Eq. 8]}$$

The resulting capital share time-series predicts the fraction of total costs that will be spent on aircraft investments. From Equation 8, the capital share varies with changes in the price of aircraft and with changes in aircraft characteristics. By multiplying this share estimate by total costs, we obtain a time-series of capital investments in aircraft.

The final pieces of information needed to calculate the number of planes in the aircraft fleet are the predicted level of aircraft prices and the average aircraft size. Both variables are defined by users of the model. The aircraft price variable can include more than simply the implicit rental price. As it reflects a more comprehensive measure of aircraft ownership costs, it can also be used to reflect the impact of changes in the productivity of aircraft. The rate of growth in aircraft size is also selected by the user, with size measured by the average number of seats. The product of the aircraft price index and the average size are divided into the aircraft investment to get the estimated number of planes in each airline's fleet. In equation form, the formula is

$$number\ of\ planes\ = \frac{capital\ share\ \times\ total\ cost}{aircraft\ price\ \times\ average\ size}. \qquad \text{[Eq. 9]}$$

The required fleets for all the airlines are then summed to get the industry estimate.

Scenarios and Forecasts

Baseline Scenario

Using the baseline values specified in Appendix C for the supply and demand variables, the ASAC Air Carrier Investment Model projects annual growth in travel demand of 4.55 percent for the period of 1994 through 2005. This prediction compares quite favorably with annual growth forecasts of 4.74 percent and 4.69 percent from the Boeing Company (Boeing) and the Federal Aviation Administration (FAA), respectively. In terms of the number of planes required to satisfy this growth in travel demand, the ASAC model projects annual growth in the U.S. commercial airline fleet of 2.36 percent for the period of 1994 through 2005. This prediction is between Boeing's forecast of a 2.13 percent annual growth and the FAA's forecast of a 3.28 percent annual growth. Other details for the baseline scenario are found in Appendix C.

Forecast of Operating Profit Margins and Fare Yields in the Baseline Scenario

When applied to the baseline scenario, our model predicts increasing profitability for the airline industry during the forecast years. For example, the industry operating profit margin rises to 8 percent by the year 2005 and continues to grow thereafter as costs fall more rapidly than fares. This is clearly unreasonable for the highly competitive airline industry.

To make the model reflect actual industry conditions more faithfully, three important characteristics of the industry need to be incorporated into the model:

- Competition among airlines that keeps operating profits at realistic levels
- Links between airline costs and fare yields
- Interdependency between fares and profitability.

The ASAC Air Carrier Investment Model accommodates these features with a straightforward extension. It builds an industry-wide target profit rate into the model. To meet the target profit rate, the model adjusts fare yields until the target is met. This approach incorporates the impact of competition into the forecast and allows the degree of competition to be set directly through the target margins. By choosing an appropriate profit rate, the user can also ensure that adequate capital is available to finance the purchase or lease of the aircraft needed to satisfy the growing demand for air travel.

As implemented in the model, separate target profit rates can be set for each of the four, five-year intervals within the forecast period. Specifying four distinct periods permits the user to include changes in the economic environment during the forecast period. For example, many financial analysts today claim that airlines will not purchase additional aircraft until their balance sheets are "repaired." One way to implement this concept is to set a higher profit margin during the first five-year interval and then reset the target at a lower, historically reasonable level. Such a scenario will keep fares and profits at a higher level for five years, while reducing the derived demand for aircraft and other inputs.

The model does not impose the margin constraint in every single year. Instead, the model iterates changes in fare yield until the target margin in the final year of each interval is satisfied. Since the model uses a constant rate of fare change within each five-year interval, the operating margin does not equal the target until the final year of the period. In practice, the profit margin moves in equal increments within the interval. If the target margins are the same at the beginning and end of the five-year interval, the margin will be the same in each year.

This approach explicitly lets fare changes be set by the degree of competition and the level of costs throughout the industry. It allows for a market-based mechanism for translating cost changes into profits and fare changes. One implication of this approach is that cost-reducing technologies will primarily

benefit the traveling public and not result in higher profits for the airlines over the long run. While some airlines may benefit for a short while, competition will eventually drive fares down as most airlines adopt the cost-reducing technology.

This analysis is consistent with economic theory and also appears to be an accurate description of the airline industry. The relatively low profit margins reported by the airline industry demonstrate the speed with which innovations and new technologies diffuse throughout the industry. The ease of entry for new airlines with access to cheap older aircraft keeps profit margins low, and it is unlikely that this situation will change in the near future.

Several alternative profit measures could be used to implement this approach in our model. We chose to use the operating profit margin, which is revenues minus operating costs, divided by revenues. The operating margin does not reflect interest paid on debts or a return to common shareholders, both important elements of cost in a capital-intensive industry such as the airlines. Capital expenses vary significantly from airline to airline, and in particular, will be strongly affected by whether the airline flies new or old aircraft.

An equally important question is what target operating margin should be used in the model. Boeing states that an operating profit margin of about 5 percent is probably required for the airline industry to remain healthy enough to meet increasing travel demands and purchase new aircraft. An examination of the historical data tends to confirm this conclusion. Figure 4 shows operating margins and the percentage change in aircraft fleets for nine major air carriers (American, Continental, Delta, Eastern, Northwest, Trans World, United, USAir, and Southwest) from 1978 through 1993. While there is clearly a great amount of variability in the year-to-year numbers, the years of greatest and most consistent growth in fleets was the mid-1980s. This was also the only extended period of profitability for the industry during these years. While the change in aircraft fleets may be somewhat skewed because of the effect of mergers over this time, the numbers clearly demonstrate a strong correlation between profitability and aircraft inventories. The results are reinforced when one considers that new aircraft deliveries in the early 1990s were frequently from orders placed much earlier. The chart demonstrates clearly the importance of incorporating a limit on airline profits in the investment model.

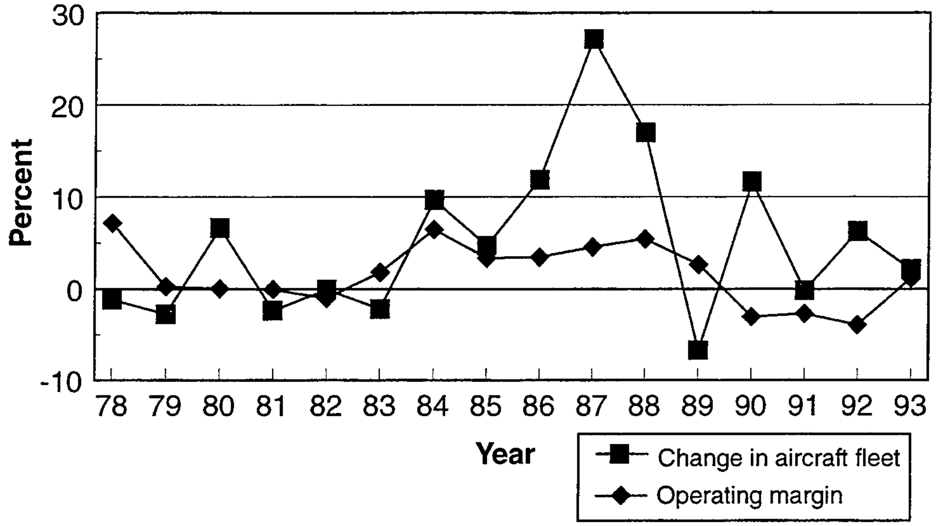

Figure 4.
Operating Profit Margins and Aircraft Fleet Growth for Nine Major Airlines

Table 3 shows the impact on the growth of revenue passenger miles (RPMs) and the U.S. aircraft fleet from varying the operating profit margin constraint. From 1995 through 2005, the model predicts that RPMs would grow 65.4 percent with a target margin of 2.5 percent. This scenario represents a low-fare environment, with fare yields falling about 1.8 percent per year from 1995 through 2005. The aircraft fleet grows by 33.2 percent during this period under the low-fare scenario. Unfortunately, the low operating profit margins will hinder the ability of the airline industry to finance the required growth in the fleet through internal cash flow or external sources.

In contrast, the high-profit scenario sees RPM growth falling to 57.7 percent over the 10-year interval. Aircraft fleet inventories grow only 27.4 percent. Although the industry has high profits with which to finance fleet expansion, there is less of a requirement to do so. The reason for the slower industry growth rates is that fares are higher. Fares fall only about 0.8 percent annually from 1995 through 2000, and then fall by 1.8 percent per year during the following five-year period.

On the basis of the historical data described by Figure 4, the low-fare, high-RPM growth scenario reflects the current competitive environment. A return to fare regulation or a wave of mergers that restrict entry by low-cost airlines could result in a more profitable industry environment with higher fares. The long-run equilibrium is likely the one envisioned by Boeing, with an operating margin of about 5 percent probably required for the airline industry to remain financially healthy enough to meet travel demands and purchase new aircraft.

Table 3.
Revenue Passenger Miles and Fleet Growth with Different Operating Profit Margins in the Baseline Scenario

Operating profit margin target	Revenue passenger-miles (billions)			Aircraft fleet		
	1995	2000	2005	1995	2000	2005
7.5%	542	664	855	4,512	4,972	5,747
Growth (%)		22.5	57.7		10.2	27.4
Annual fare changes (%)		– 0.84	– 1.82			
5.0%	545	684	880	4,532	5,108	5,905
Growth (%)		25.5	61.6		12.7	30.3
Annual fare changes (%)		– 1.32	– 1.81			
2.5%	548	704	905	4,551	5,243	6,061
Growth (%)		28.6	65.4		15.2	33.2
Annual fare changes (%)		– 1.79	– 1.81			

Sensitivity Analysis with Operating Profit Constraint in the Baseline Scenario

The enhanced model can now be used to calculate the direct and secondary effects of cost changes in the industry. By holding operating profit margins constant at the 5 percent target, changes in fuel prices or other inputs can be logically allocated between airline industry profit and fare effects. Table 4 shows the effects of changes in fuel prices over the forecast period. The baseline scenario assumes a 0.9 percent annual increase in the real price of fuel. For the sensitivity analysis, we use annual changes of 1.0 percentage point above and below the baseline value.

As Table 4 shows, changes of 1.0 percentage point per year in the growth of energy prices measurably affect industry forecasts.[5] With energy prices rising 0.9 percent annually and operating profit margins set at 5 percent, total airline industry output rises 61.6 percent from 1995 through 2005. If energy prices fall by 0.1 percent per year, RPMs grow by 64.1 percent. Conversely, if energy prices rise by 1.9 percent annually, airline industry output rises only 58.8 percent.

[5] This is a *ceteris paribus* analysis where a single factor — the price of energy — is allowed to vary while all other factors are held constant. In this regard, this illustrative sensitivity analysis differs from the "oil price shock" scenario discussed later in this report.

The difference in the size of the industry-wide aircraft fleet in the year 2005 under cases of higher and lower energy prices is 221 planes. At an average $66 million per aircraft, this amounts to a swing in revenues of $14.6 billion for the aircraft manufacturing industry.

Table 4.
Effects of Fuel Price Changes in the Baseline Scenario

Energy price change	Revenue passenger-miles (billions)			Aircraft fleet		
	1995	2000	2005	1995	2000	2005
1.9%	544	676	863	4,525	5,056	5,794
Growth (%)		24.4	58.8		11.7	28.0
Annual fare changes (%)		– 1.15	– 1.65			
0.9%	545	684	880	4,532	5,108	5,905
Growth (%)		25.5	61.6		12.7	30.3
Annual fare changes (%)		– 1.32	– 1.81			
– 0.1%	546	691	896	4,539	5,160	6,015
Growth (%)		26.6	64.1		13.7	32.5
Annual fare changes (%)		– 1.49	– 1.95			

Other Scenarios: Comparisons

To demonstrate the reasonableness and utility of our model, we evaluated a set of alternative scenarios. These are summarized in Table 5. As noted earlier, the general effect of the 5 percent operating margin target is to pass some of the benefit to the traveling public during favorable scenarios and to pass some of the costs to the traveling public when the scenario is unfavorable. Lower or higher airfares are the mechanism for transmitting the benefits or costs to consumers. For example, when economic growth is high and unemployment is low, holding operating profit margins to 5 percent results in lower airfares than would otherwise occur. This increases the growth rate for travel demand and the number of aircraft in the fleet. Conversely, when there is an oil price shock, the 5 percent operating profit margin target means that the traveling public absorbs some of the increase in the price of energy through higher airfares. Consequently, travel demand grows less rapidly and the number of aircraft in the fleet shrinks more than when the profit targets are not binding. Details of the scenario forecasts and illustrative printouts from the ASAC Air Carrier Investment Model are in Appendix D.

Table 5.
Baseline and Other Scenario Forecasts

Scenario	Annual change for affected variables (%)	Baseline values (%)	Growth in travel demand (1995 – 2005) (%)	Growth in aircraft fleet (1995 – 2005) (%)	Industry operating margins in 2005 (%)
Baseline			4.55	2.36	8.0
High growth with low employment	Income = 3.0 Unemployment rate = – 1.0	2.5 0.0	5.34	3.07	8.6
When operating margin targets are binding			5.83	3.58	5.0
Oil price shock	Income = 0.0 Energy price = 2.0	2.5 – 1.6	1.22	– 0.61	– 1.9
When operating margin targets are binding			0.60	– 1.15	5.0
Airline fare war	Fare yield = – 2.0	– 1.23	5.38	3.10	0.4
When operating margin targets are binding			5.00	2.81	5.0

Conclusion

To link the economics of flight with the technology of flight, NASA's Aviation System Analysis Capability (ASAC) requires a parametrically based model that links airline operations and investments in aircraft with aircraft characteristics. That model also must provide a mechanism for incorporating air travel demand and profitability factors into the airlines' investment decisions. Finally, the model must be flexible and capable of being incorporated into a wide-ranging suite of economic and technical models that are envisioned for ASAC.

The ASAC Air Carrier Investment Model meets all of these requirements. The prototype model incorporates econometric results from the supply and demand curves faced by U.S. air carriers. It provides analysts with the ability to project revenue passenger-miles flown, number of aircraft in the fleet, and operating margins under various user-defined scenarios. The model also demonstrates the feasibility of incorporating sophisticated regression results into a user-friendly spreadsheet environment. Future work will involve refining the

econometric results, and the spreadsheet may be replaced with programming code.

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APPENDIX A

Data Description

INTRODUCTION

The airline production data set includes four inputs: labor; energy; flight capital; and a residual category called materials that includes supplies, outside services, and nonflight capital. The data set also includes two outputs: scheduled and nonscheduled revenue passenger-miles — and two network traits: stage length and load factor. Flight capital is described by four aircraft attributes: the average size (measured in seats); the average age; and the separate proportions of aircraft in the fleet that are jet powered or wide-bodied designs.

The most comprehensive data set includes information for the 17 largest U.S. air carriers that were operating at the time of deregulation, or their descendant airlines. The carriers included are American, Eastern, Trans World, United, Braniff International, Continental, Delta, Northwest, Western, USAir, Frontier, North Central, Piedmont, Ozark, Southern, Republic, and Texas International. This provides nearly total coverage of scheduled air traffic in 1970, the beginning of the data, to roughly three-quarters of the scheduled air traffic by 1990, the data set's end. This information is quarterly, air-carrier-specific information and results in 1,137 total observations. Attention was restricted to the traditional certificated carriers because routine data reporting was well-established for them at the time of deregulation. New entrants can be added to this data set with some difficulty. However, it should be remembered that these carriers have little experience in providing the often burdensome reporting required by Department of Transportation (DOT) Form 41 and that noncompliance results in virtually no sanctions. Consequently, new entrant data tends to be of significantly lower quality. The version of the data described in more detail below provides the largest, cleanest data available on the production of U.S.-scheduled passenger air transport.

The procedure used in constructing the data set has changed considerably over the last decade. As more and more data sources become available, it will change further. One of the most significant factors in these changes has been an adaptation to the changes in the reporting requirements of DOT Form 41. In order to maintain comparability over time, data from all versions of Form 41 must be mapped into a single version. The latest significant revision, which occurred in 1987, eliminated many of the specific functional accounts that were used previously. The most significant changes occurred in the areas of labor, supplies, and outside services. This latest version of Form 41 data is the most restrictive in that it provides the least detail in most cases. In other instances, the 1985 revision of Form 41 data is somewhat more restrictive. However, many of these changes were in place for only a short period of time. Where the 1985

restrictions were most severe, 1987-equivalent accounts were estimated. This occurred most seriously in the area of ground-based capital, where lease payments and capitalized leases had to be allocated between flight and ground capital. In other cases, it seemed reasonable to estimate 1985 accounts from the 1987 data provided. The objective was to maintain as much detail as possible in all areas of air carrier production.

The construction of the individual input and output categories is described in the next several sections. In cases where price and quantity pairs for a specific input or output are constructed, several subcomponents to that input or output are first constructed. Then these are aggregated into a single input or output using a multilateral Tornqvist-Theil index number procedure.[1] The result of this procedure is a price index (much like the consumer price index) that aggregates price information for commodities having disparate physical units. When total expenditures of the input or output category are divided by this price index, an implicit quantity index is produced.

LABOR

The labor input was composed of 93 separate labor accounts aggregated into five major employment classes (flight deck crew, flight attendants, mechanics, passenger/cargo/aircraft handlers, and other personnel). This is shown in Table A-1. We do not attempt to correct for differing utilization rates since we do not have information on the number of hours worked by the labor inputs. Expenditures in these five subcomponents are constructed from the expenditure data in DOT Form 41 Schedules P5, P6, P7, and P8.

Following the 1987 modification in Form 41, Schedules P7 and P8 were dramatically simplified, eliminating many separate expense accounts. Mechanics and Handlers appear as lines 5 and 6 of the new Schedule P6. In order to be more compatible with the new Schedule 6, trainees and instructors were moved into the Other Personnel category. Flight attendant expense was calculated by subtracting accounts 5123 and 5124 from Schedule P5 from line 4 (total flight personnel) on the new Schedule P6.

Other labor-related expenses — such as personnel expenses, insurance, pension, and payroll taxes — were included as labor expenses. The labor-related expenses, accounts, and schedules from which they were obtained are listed in Table A-2.

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[1] This mathematical technique derives indexes from underlying utility, cost, production, revenue, profit, or transformation functions. In this case, the transcendental logarithmic (translog) cost function is underlying, and expenditure shares are used to weight each subcomponent's contribution to the overall index number. For a detailed explanation, refer to Diewert (1976); Caves, Christensen, and Diewert (1982); and Good, Nadiri, and Sickles (1992) in the Bibliography.

Table A-1.
Labor Costs

Schedule	Accounts	Subcomponent
P5	5123+5124	Flight deck crew
P6	5524	Flight attendants
P5, 6	5225.1+5225.2+5225.3+5225.9+5325.9+ 5328.1+5328.2	Mechanics
P7, 8	6126.1+6126.2+6128.1+6226.1+6226.3+ 6228.1+6326.1+6328.1+6526.1+6526.3+ 6526.4+6528.1+6628.1+6828.1	Passenger/cargo/aircraft handlers
P6, 7, 8	5330+5331+5334+5335+5530+5531+5535+ 6130+6131+6135+6230+6231+6235+6330+ 6331+6335+6530+6531+6533+6535+6630+ 6631+6635+6830+6831+6832+6834+6835+ 5128.1+5528.1	Other personnel

Table A-2.
Labor-Related Expenses

Schedule	Accounts	Subcomponent
P5, 6, 7, 8	5136+5336+5536+6136+6236+6336+6536+ 6636+6836	Personnel expenses
P5, 6, 7, 8	5157+5357+5557+6157+6257+6357+6557+ 6657+6857	Insurance and pension
P5, 6, 7, 8	5168+5368+5568+6168+6268+6368+6568+ 6668+6868	Payroll taxes

Since labor-related expenses are provided on functional lines rather than on an employment class basis, they were allocated to each of the five employment groups on the basis of the expenditure share of that class. After the 1987 Form 41 changes, these three expenditure categories are provided on Schedule P6 as lines 10, 11, and 12, respectively.

The accounts and schedules from the DOT Form 41, from which the carrier employment quantity data were obtained, are shown in Table A-3.

The quarterly total head count of full-time equivalent personnel was found by averaging the monthly full-time personnel plus one-half of the part-time employees over the relevant quarter.

Table A-3.
Labor Headcounts

Schedule	Accounts	Subcomponent
P10	5123+5124	Flight deck crew
P10	5524	Flight attendants
P10	25	Mechanics
P10	6126.1+6226.1+6326.1+6526.1+6126.2+ 6226.3+6526.3+6226.4+6526.4+7100	Passenger/cargo/aircraft handlers
P10	99 minus accounts above	Other personnel
P1A	—	Full-time employees
P1A	—	Part-time employees

In 1977, Schedule P10 was changed from a quarterly to an annual filing cycle. This meant that allocations of head counts into specific employment categories could not be done directly except for the fourth quarter of each calendar year. Instead, the distribution of head counts among the five labor groups was interpolated using the annual figures. The estimated head count in each group was found by multiplying the interpolated percentage by the calculated full-time equivalent headcount for that quarter. In 1983, Schedule P10 was simplified. This simplification collapsed the handlers category into a smaller number of separate accounts, but did not change the overall structure of our procedure.

Using the expense and head count information from above, the expense per person quarter and the number of person quarters were calculated. The multilateral Tornqvist-Theil price and quantity indices for the labor input were then derived.

ENERGY

The objective of the energy input category is to capture aircraft fuel only. Fuel that is used for ground operations and electricity are both captured in the materials index. The energy input was developed by combining information on aircraft fuel gallons used with fuel expense data per period. The schedules and accounts are listed in Table A-4.

Table A-4.
Energy Costs and Quantities

Schedule	Accounts	Subcomponent
P5	5145.1	Aircraft fuel (cost in dollars)
T2	Z921	Aircraft fuel (gallons)

This input has undergone virtually no change because these accounts remained substantially unchanged over the 23-year span of our data set. Even though only one component exists, the multilateral Tornqvist-Theil index number procedure is used to provide normalization of the data.

MATERIALS

The materials input is comprised of 69 separate expenditure accounts aggregated into 12 broad classes of materials or other inputs that did not fit into the labor, energy, or flight capital categories. Carrier-specific price or quantity deflators for these expenditure groups were unavailable. Instead, industry-wide price deflators were obtained from a variety of sources. These price deflators were normalized to 1.0 in the third quarter of 1972. The classification of these expenditure accounts are presented below along with the corresponding source for the price deflator.

In 1987, the modifications of Schedules P6 and P7 led to the elimination of hundreds of separate account categories. In most cases, this did not affect the ability to reconstruct the categories listed in Table A-5. The sources of information did change, however. Advertising expense, passenger food, and landing fees appear as line 22, line 6, and line 12 of the new Schedule P7, respectively. Expenses for aircraft maintenance materials, communications, insurance, outside services and outside maintenance, and passenger and cargo commissions appear as line 17, line 23, line 24, line 25 + line 28, and line 26 + line 27 of the new Schedule P6. Ground equipment rental expense was line 31 of Schedule P6 minus account 5147 from Schedule P5. Amounts for other supplies and utilities appear aggregated together as line 19 of new Schedule P6. These amounts were apportioned to the supplies and utilities categories using the carrier's average proportion in these groups over the 1981 through 1986 periods. Ground equipment that is owned was unaffected by the 1987 accounting changes.

Table A-5.
Materials

Schedule	Accounts	Price index	Classification
P5	5246.1+5246.2+5246.3+ 5243.1+5243.2+5243.3	Producer prices: metals and metal products	Aircraft maintenance materials
P8	6660+6662	McCann Erickson Advertising Index	Advertising
P6, 7, 8	5337+5537+6137+6237+ 6337+6537+6637+6837	Consumer prices: telephone services	Communications
P5, 6	5155.1+5355.1+6855.1+ 6256.0+5556.0	Industry average expense per aircraft mile flown	Insurance
P6, 7, 8	5243.9+5343.9+5543.9+ 6143.9+6243.9+6343.9+ 6543.9+6643.9+6843.9	Gross National Product (GNP) deflator for services	Outside services and aircraft maintenance
P6, 7, 8	5350+5550+6150+6250+ 6350+6550+6650+6850+ 5353+5553+6153+6253+ 6353+6553+6653+6853+ 5354+5554	Producer prices: total manufacturing nondurables	Supplies
P6, 7, 8	5338+5538+6138+6238+ 6338+6538+6638+6838	Consumer prices: electric, gas (89%), and sanitary service (11%)	Utilities
P6	5551	Producer prices: processed foods	Passenger food
P8	6539.1+6539.2	Consumer prices: air fares	Commissions
P6, 7, 8	5347+5547+6147+6247+ 6347+6547+6647+6847	GNP deflator for nonresidential fixed investment	Ground equipment, rented
B1, P6, 7	(See note below)	Jorgensen-Hall user price	Ground equipment, owned
P7	6144	Landing fees per capacity-ton landed	Landing fees

Note: Total expenditures associated with ground equipment and structures were calculated using a perpetual inventory method with a 1958 benchmark, assuming a 20-year expected life, straight-line depreciation, and interest rates assuming a Moody's BAA bond rating. The tax advantages, including investment tax credits (along with the special transition rules under the 1986 tax revisions) relevant at the time were also incorporated into the carrier's expenditure on ground capital owned. As with the labor index, a multilateral Tornqvist-Theil index number procedure was used to generate price quantity combinations for each carrier at each quarter over the 23-year span of the data.

Flight Capital

The number of aircraft that a carrier operated for each different model of aircraft in the airline's fleet was collected from DOT Form 41, Schedule T2 (account Z820). Data on the technological characteristics for the approximately 60 types of aircraft in significant use over the period 1970 through 1992 were collected from *Jane's All the World's Aircraft* (1945 through 1982 editions).

First, for each quarter, the average number of aircraft in service was constructed by dividing the total number of aircraft days for all aircraft types by the number of days in the quarter. This provides a gross measure of the size of the fleet (number of aircraft).

In order to adjust this measure of flight capital, we also construct the average equipment size. This was measured with the highest density single-class seating configuration listed in *Jane's* for each aircraft type. The fleetwide average was weighted by the number of aircraft of each type assigned into service. In some cases, particularly with wide-bodied jets, the actual number of seats was substantially less than described by this configuration because of the use of first-class and business-class seating Our purpose was to describe the physical size of the aircraft rather than how carriers chose to use or configure them.

We use the average number of months since the Federal Aviation Administration's type-certification of aircraft designs as our measure of fleet vintage. Our assumption is that the technological innovation in an aircraft does not change after the design is type-certified. Consequently, our measure of technological age does not fully capture the deterioration in capital and increased maintenance costs caused by use. Our measure does capture retrofitting older designs with major innovations, if these innovations were significant enough to require recertification of the type.

Finally, it is clear that the major innovation that took place during the 1960s and 1970s was the conversion to jet aircraft. While many carriers had largely adopted this innovation prior to the study period, it was by no means universal. Many of the local service airlines used turboprop aircract as a significant portion of their fleets. We implement this aspect by measuring the proportion of aircraft in the fleet that are jet powered. The proportion of wide-bodied aircraft was also calculated.

Output

Our data set provides several measures of airline output and its associated characteristics. The most commonly used measure of carrier output is the revenue ton-mile. Our data set provides this measure as well as measures of revenue output that are disaggregated into scheduled and nonscheduled output. Nonscheduled output includes cargo and charter operations. We further provide measures of airline capacity. This again can be disaggregated into

scheduled and nonscheduled operations. Revenue and traffic data were available from DOT Form 41. These data allowed us to construct price and quantity figures for seven different outputs produced by the typical airline. These different services and the accounts from which the revenue data were obtained are given in Table A-6. Again, the price per unit (passenger-mile or ton-mile) of the relevant service was constructed by dividing the revenue generated in the category by the physical amount of output in that category. These prices were normalized to 1.0 in the baseline period (the third quarter of 1972).

Table A-6.
Carrier Revenues and Ouput Quantities

Schedule	Accounts	Type of service
P3 T1	3901.1 K141	First class passenger revenue First class passenger-miles
P3 T1	3901.2 K142	Coach passenger revenue Coach passenger-miles
P3 T1	3905 Z243+Z244+Z245	Mail transportation revenue Mail ton-miles
P3 T1	3906.1 K246	Express cargo revenue Express cargo ton-miles
P3 T1	3906.2 K247	Air freight revenue Air freight ton-miles
P3 T1	3907.1 V140	Charter passenger revenue Charter passenger-miles
P3 T1	3907.2 V246+V247	Charter cargo revenue Charter cargo ton-miles

In cases where a carrier offered only one type of service (the convention was to call this "first class"), the service was redefined to be coach class. The reporting of revenue and traffic in charter operations between cargo and passenger service was very sporadic. These two outputs were combined into a single category with passenger-miles converted to ton-miles, assuming an average weight of 200 pounds per passenger (including baggage). Changes in DOT Form 41 in 1985 led to the elimination of the distinction between express cargo and air freight. Consequently, these two categories were also collapsed.

Three different price and quantity index pairs are generated. The first is total revenue-output and uses the multilateral Tornqvist-Theil index number procedure on all of the revenue-output categories. The second uses the Tornqvist-Theil index number procedure on the two passenger categories. The third results from the use of the index number procedure on mail, cargo, and charter services.

The capacity of flight operations is also provided in our data set. This describes the total amount of traffic generated, regardless of whether or not it

was sold. While it is possible to distinguish between an unsold coach seat and an unsold first-class seat (they are of different sizes), such distinctions are not logically possible in the case of cargo operations (mail and cargo could be carried in the same location). Consequently, our measure of airline capacity includes only three broad categories: first-class seat-miles flown, coach seat-miles flown, and nonscheduled ton-miles flown. The accounts and schedules from Form 41 are shown in Table A-7.

Table A-7.
Capacity Measures

Schedule	Accounts	Type of service
T1	K321	First-class seat-miles
T1	K322	Coach seat-miles
T1	Z280 – (K321+K322)/10	Nonscheduled ton-miles

With the change to T100 as the primary data base for airline traffic in 1990, carriers are no longer required to report available seat-miles, revenue seat-miles, or revenues by the level of passenger service. Instead, these amounts are aggregated with revenues supplied as account 3901 on Schedule P1 after 1990.

Again, the convention that a passenger along with baggage is 200 pounds (one-tenth of a ton) is used to construct the nonscheduled ton-miles. Potential revenues that could be collected, if all services were sold, are constructed assuming that the prices for each of these categories remain the same as for output actually sold. In other words, the price for first-class revenue passenger-miles flown is imputed to first-class available seat-miles flown. Again, the Tornqvist-Theil index number procedure is used to generate price and quantity pairs for total capacity output, passenger capacity output, and nonscheduled capacity output.

Two important measures of the carrier's network are also generated. The first is a passenger load factor. This is found by dividing revenue passenger-miles by available seat-miles [i.e., (K141+K142)/(K321+K322)]. This measure is generally related to flight frequency with a lower number indicating more frequent flights and consequently a higher level of service. Other definitions of load factor are possible, such as dividing the total passenger revenue collected (3901.1+3901.2) by the total that would be collected were the planes flown full (derived from the passenger capacity output times passenger capacity price). If desired, these can easily be constructed using information in the data set. Stage length also provides an important measure of carrier output. Generally, the shorter the flight, the higher the proportion of ground services required per passenger-mile and the more circuitous the flight (a higher proportion of aircraft miles flown is needed to accommodate the needs of air traffic control). This generally results in a higher cost per mile for short flights than for longer flights.

Average stage length is found by dividing total revenue aircraft miles flown (Z410) by total revenue aircraft departures (Z510).

Appendix B

User's Guide

Introduction

The spreadsheet was constructed using Lotus 1-2-3 for Windows, Release 4, and the file is called LMIMODEL.WK4. These instructions presume that the user is moderately familiar with Lotus 1-2-3 commands.

Making Changes to Supply and Demand Factors

After loading the spreadsheet into memory (following the usual procedures), the user should cursor to cell B3 of the top sheet (labeled ROLLUP). This cell is the first of seven demand variables that may be changed by the user and corresponds to the projected annual percentage change in real (or constant dollar) fare yield over the forecast period 1994 through 2000. Cells B4 to B6 represent the projected changes in fare yields for the periods 2001 through 2005, 2006 through 2010, and 2011 through 2015, respectively. In the baseline scenario, all four of these variables are set to – 1.23 percent. Because all of the demand variables are expressed in percentage terms, a value of 1 percent should be entered in a cell as "1" rather than ".01". Cell B7 is the projected annual change in real national income for the 21-year forecast period and is set at 2.5 percent for the baseline. Cell B8 is the projected population growth and cell B9 is the forecast annual percentage change in the level of the unemployment rate. In the baseline scenario, these two figures are set at 0.94 percent and 0.0 percent, respectively.

By moving the cursor down to cell B12, the user encounters the first of 10 supply variables that may be changed. Cells B12 through B15 are the forecast annual changes in factor prices (labor, energy, materials, and capital). Because the model uses constant 1994 dollars, these annual factor price changes should be interpreted as real price changes. Productivity improvements can also be modeled as effective price reductions. For example, the – 1.6 percent price change for energy reflects a 0.9 percent increase in the price of jet fuel combined with a 2.5 percent decrease in block fuel burned (reflecting an increase in engine/airframe fuel efficiency). Cells B16 and B17 are network variables and reflect the projected annual changes in stage length and load factor. In the baseline scenario, these are set at 0.35 percent and 0.15 percent, respectively. The next four cells are capital attribute variables. Cells B18 and B19 are the projected changes in the average seats per aircraft and the average age of aircraft in the fleet, respectively. In the baseline scenario, these figures are set at 0.75 percent and 0.0 percent. Cells B20 and B21 are the annual changes in the percentages of

jets and wide-bodied aircraft in the fleet, respectively. It is important to note that these two figures are the only supply or demand variables not expressed in percentage terms. In the baseline scenario, they are set at 0.0 and 0.0004909.

The model also can calculate the annual changes in fare yield required to hit desired operating margin levels at four points in the future. In cells B27 through B30, the user may designate the target operating margins for the years 2000, 2005, 2010, and 2015, respectively.

Interpreting the Results

As changes are made to the supply and demand variables, the spreadsheet automatically adjusts the forecast. Changes from the baseline scenario may be inspected visually by cursoring down to cell A55, the first of three embedded graphs. The first graph plots the projected growth in domestic and international travel demand faced by U.S. passenger air carriers. The units of measurement are billions of revenue passenger-miles. By pressing the "page down" key once, the user comes to the second graph. This graph shows the projected size of the fleet required to satisfy the level of forecasted air travel demand. By pressing the "page down" key once more, the user comes to the final graph. This graph depicts the forecasted aggregate operating margin for U.S. passenger air carriers. Operating margin is defined as total revenues minus total operating costs, divided by total revenues. In addition to viewing them, the user may also cursor to the right of the graphs to inspect the underlying data.

If the user believes that the forecasted industry-level operating margin is either too high or too low, adjustments to the fare yield variables can be made by clicking once on the button labeled "Backsolve" or by running the macro called "Backsolver" under the Tools menu of commands. The backsolver algorithm calculates the projected annual changes in fare yields required to achieve the four target operating margins set previously. Additionally, a macro has been written that returns all 17 supply and demand variables to the levels defined as the baseline scenario. This macro is executed by clicking once on the button labeled "Reset" or by running the macro called "Reset" under the Tools menu of commands. Finally, a macro is available to print the three graphs with their corresponding data and a table that compares the values of supply and demand variables under the user-defined scenario and the baseline. This macro can be executed by clicking once on the button labeled "Print" or by running the macro called "Printer" under the Tools menu of commands.

Technical Note

The macro ranges could not be named "backsolve" or "print" because these are macro command keywords (and hence are prohibited).

APPENDIX C

Baseline Scenario

DEFAULT VALUES

Table C-1 shows the default values for the annual changes (from 1994 through 2015) of the key variables in the ASAC Air Carrier Investment Model.

Table C-1.
Default Values

Variable	Boeing[a]	Federal Aviation Administration[b]	LMI
Change in fare yield	– 0.85%	– 1.60%	–1.23%
Income growth	2.50%	2.50%	2.50%
Population growth	—	—	0.940%
Change in unemployment rate	—	—	0.00%
Labor price change	– 1.60% (reflects constant wages minus labor productivity increase)	—	– 1.60%
Fuel price change	– 1.60% (reflects 0.9% increase in fuel price minus 2.5% increase in fuel efficiency)	—	–1.60%
Materials price change	—	—	0.00%
Capital price change	– 0.40% (reflects more miles flown per year per aircraft)	– 0.60% (reflects more airborne hours per year per aircraft)	–0.50%
Change in stage length	—	0.35%	0.35%
Change in load factor	0.30%	0.00%	0.15%
Change in average seats per aircraft	0.60%	0.90%	0.75%
Change in average age of aircraft	—	—	0.00%
Change in percentage of jet aircraft	—	—	0.00
Change in percentage of wide-bodied aircraft	—	0.0004909	0.0004909

Note: All economic values are measured in constant dollars. Therefore, the annual percentage changes are real rates of change.

[a] The Boeing figures are an amalgamation of forecasts from the 1993 and 1994 editions of their *Current Market Outlook*. If forecasts from both years were available, preference was given to the 1994 edition. Additionally, preference was given to U.S.-specific forecasts; otherwise, worldwide forecasts were substituted.

[b] The FAA figures were derived from *FAA Aviation Forecasts: 1995-2006*. The FAA focuses exclusively on U.S. carriers.

Forecasted Values

When the consensus figures are inserted into the ASAC Air Carrier Investment Model, the values of future travel and aircraft requirements, shown in Table C-2, are predicted for the period 1994 through 2005. These forecasts may be compared with those from Boeing and the FAA.

Table C-2.
Forecasted Values

Variable	Boeing[a]	FAA[b]	LMI
Revenue passenger-mile (RPM) growth	4.740%	4.688%	4.552%
Absolute RPMs (billions) in 2005	888.5	856.8	849.5
Growth in number of aircraft	2.13%	3.28%	2.36%
Absolute number of aircraft in 2005	5,424	6,309	5,715

[a] The Boeing figures are an amalgamation of forecasts from the 1993 and 1994 editions of their *Current Market Outlook*. If forecasts from both years were available, preference was given to the 1994 edition. Additionally, preference was given to U.S.-specific forecasts; otherwise, worldwide forecasts were substituted.

[b] The FAA figures were derived from *FAA Aviation Forecasts: 1995 – 2006*. The FAA focuses exclusively on U.S. carriers.

Appendix D

Details of Alternative Scenarios

High Growth and Low Unemployment

In a high-growth and low-unemployment scenario, economic growth accelerates to 3 percent per year relative to the baseline 2.5 percent growth rate. Consequently, the unemployment rate falls from 6 percent in 1994 to 4.9 percent in 2015.

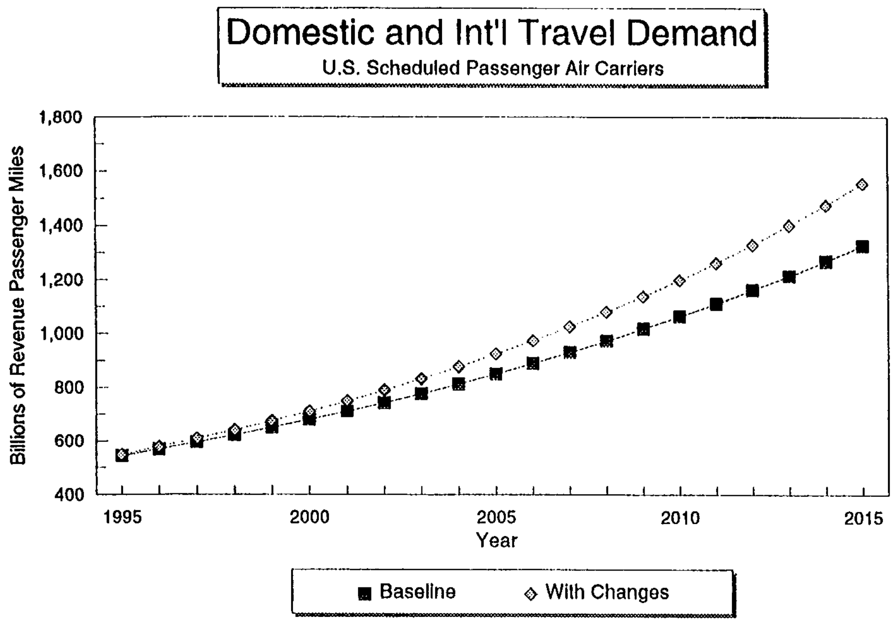
Because of this robust macroeconomic environment, growth in the consumer demand for passenger air travel increases to 5.34 percent. Consequently, the derived demand for aircraft and airline operating margins both improve.

As shown in the second set of printouts, if the target operating margins of 5 percent apply, then fares will decline relative to the baseline and the increase in passenger air travel, and the derived demand for aircraft would be even greater. See the following spreadsheet printouts for details.

INDUSTRY ROLLUP	Annual	Baseline
Demand variables:	Change (%)	Scenario
Fare yield, 1995 to 2000	-1.23	-1.23
Fare yield, 2001 to 2005	-1.23	-1.23
Fare yield, 2006 to 2010	-1.23	-1.23
Fare yield, 2011 to 2015	-1.23	-1.23
Income	3.00	2.50
Population	0.94	0.94
Unemployment rate	-1.00	0.00
Supply variables:		
Price of labor	-1.60	-1.60
Price of energy	-1.60	-1.60
Price of materials	0.00	0.00
Price of capital	-0.50	-0.50
Stage length	0.35	0.35
Load factor	0.15	0.15
Seats per A/C	0.75	0.75
Age of A/C	0.00	0.00
Percent jets*	0.0000000	0.0000000
Percent wide body*	0.0004909	0.0004909

*Note: not a percentage change, coefficients modified to reflect

	Target operating margins (%)
By year 2000	N/A
By year 2005	N/A
By year 2010	N/A
By year 2015	N/A



Year	Revised Total RPM (billions)	Baseline Total RPM (billions)
1995	548.372	544.267
1996	577.661	569.044
1997	608.515	594.950
1998	641.016	622.035
1999	675.253	650.352
2000	711.319	679.959
2001	749.311	710.914
2002	789.332	743.278
2003	831.490	777.115
2004	875.901	812.493
2005	922.683	849.481
2006	971.965	888.154
2007	1,023.878	928.586
2008	1,078.564	970.860
2009	1,136.171	1,015.058
2010	1,196.854	1,061.268
2011	1,260.779	1,109.581
2012	1,328.118	1,160.094
2013	1,399.054	1,212.907
2014	1,473.778	1,268.124
2015	1,552.494	1,325.854
Growth	5.34%	4.55%

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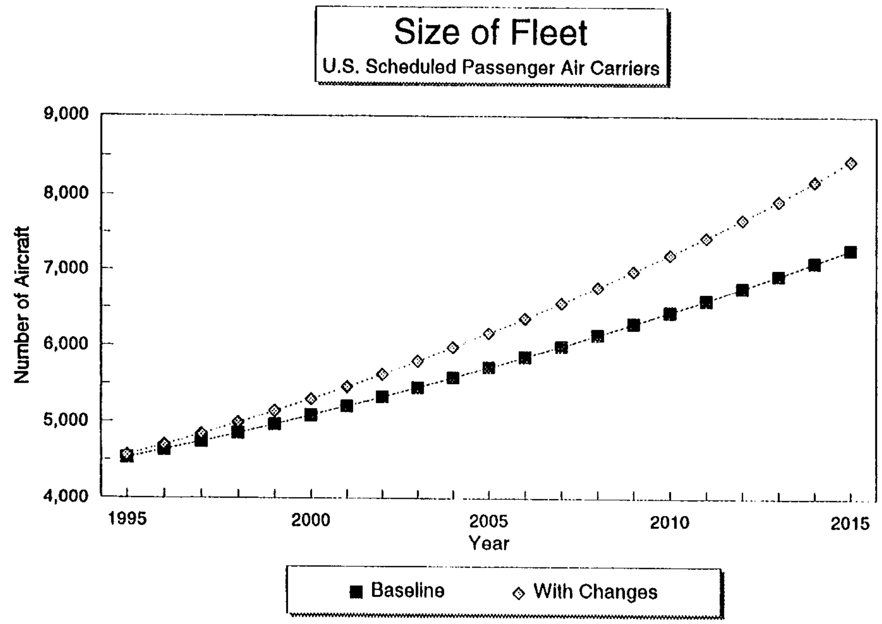

Year	Revised Number of A/C	Baseline Number of A/C
1995	4,559	4,528
1996	4,696	4,633
1997	4,838	4,740
1998	4,985	4,851
1999	5,137	4,965
2000	5,295	5,081
2001	5,457	5,201
2002	5,626	5,325
2003	5,800	5,451
2004	5,981	5,581
2005	6,168	5,715
2006	6,361	5,853
2007	6,561	5,994
2008	6,768	6,140
2009	6,983	6,289
2010	7,206	6,443
2011	7,436	6,601
2012	7,674	6,763
2013	7,922	6,930
2014	8,178	7,102
2015	8,443	7,279
Growth	3.13%	2.40%

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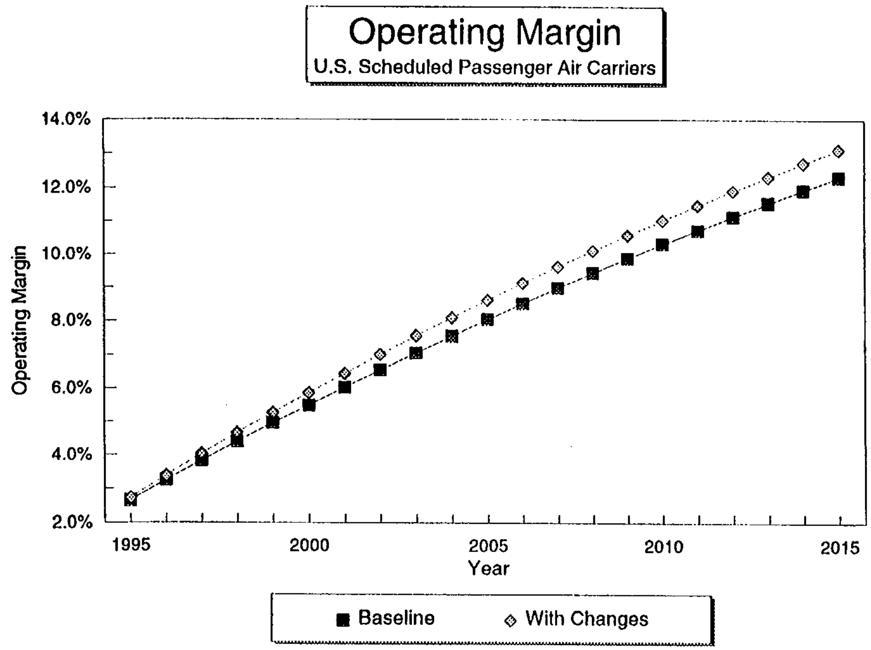

Year	Revised Operating Margin	Baseline Operating Margin
1995	2.7%	2.7%
1996	3.4%	3.3%
1997	4.0%	3.8%
1998	4.7%	4.4%
1999	5.3%	5.0%
2000	5.9%	5.5%
2001	6.4%	6.0%
2002	7.0%	6.5%
2003	7.6%	7.1%
2004	8.1%	7.5%
2005	8.6%	8.0%
2006	9.1%	8.5%
2007	9.6%	9.0%
2008	10.1%	9.4%
2009	10.6%	9.9%
2010	11.0%	10.3%
2011	11.5%	10.7%
2012	11.9%	11.1%
2013	12.3%	11.5%
2014	12.7%	11.9%
2015	13.1%	12.3%
Growth		

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INDUSTRY ROLLUP	Annual	Baseline
Demand variables:	Change (%)	Scenario
Fare yield, 1995 to 2000	-1.39	-1.23
Fare yield, 2001 to 2005	-1.86	-1.23
Fare yield, 2006 to 2010	-1.78	-1.23
Fare yield, 2011 to 2015	-1.71	-1.23
Income	3.00	2.50
Population	0.94	0.94
Unemployment rate	-1.00	0.00
Supply variables:		
Price of labor	-1.60	-1.60
Price of energy	-1.60	-1.60
Price of materials	0.00	0.00
Price of capital	-0.50	-0.50
Stage length	0.35	0.35
Load factor	0.15	0.15
Seats per A/C	0.75	0.75
Age of A/C	0.00	0.00
Percent jets*	0.0000000	0.0000000
Percent wide body*	0.0004909	0.0004909

*Note: not a percentage change, coefficients modified to reflect

	Target operating margins (%)
By year 2000	5.00
By year 2005	5.00
By year 2010	5.00
By year 2015	5.00

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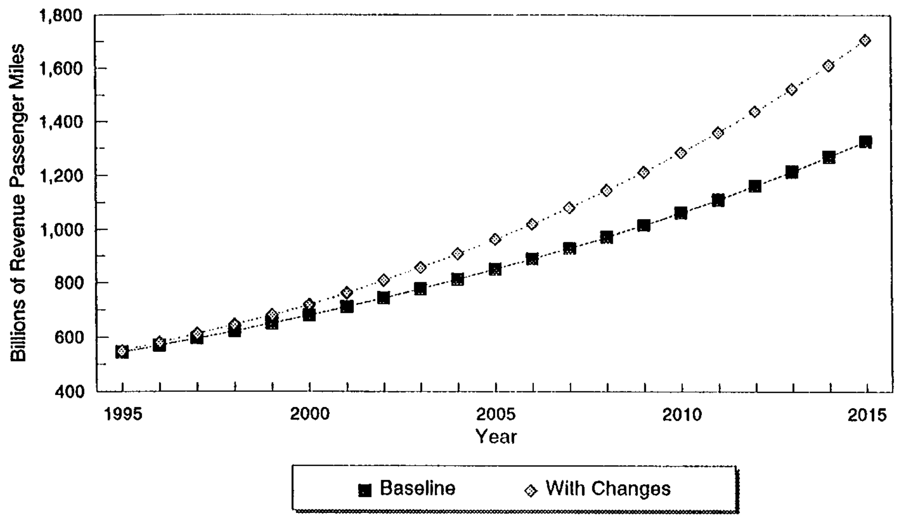
Domestic and Int'l Travel Demand

U.S. Scheduled Passenger Air Carriers



Year	Revised Total RPM (billions)	Baseline Total RPM (billions)
1995	549.282	544.267
1996	579.579	569.044
1997	611.547	594.950
1998	645.279	622.035
1999	680.871	650.352
2000	718.426	679.959
2001	761.639	710.914
2002	807.451	743.278
2003	856.019	777.115
2004	907.508	812.493
2005	962.094	849.481
2006	1,019.177	888.154
2007	1,079.647	928.586
2008	1,143.705	970.860
2009	1,211.564	1,015.058
2010	1,283.449	1,061.268
2011	1,358.587	1,109.581
2012	1,438.124	1,160.094
2013	1,522.317	1,212.907
2014	1,611.439	1,268.124
2015	1,705.778	1,325.854
Growth	5.83%	4.55%

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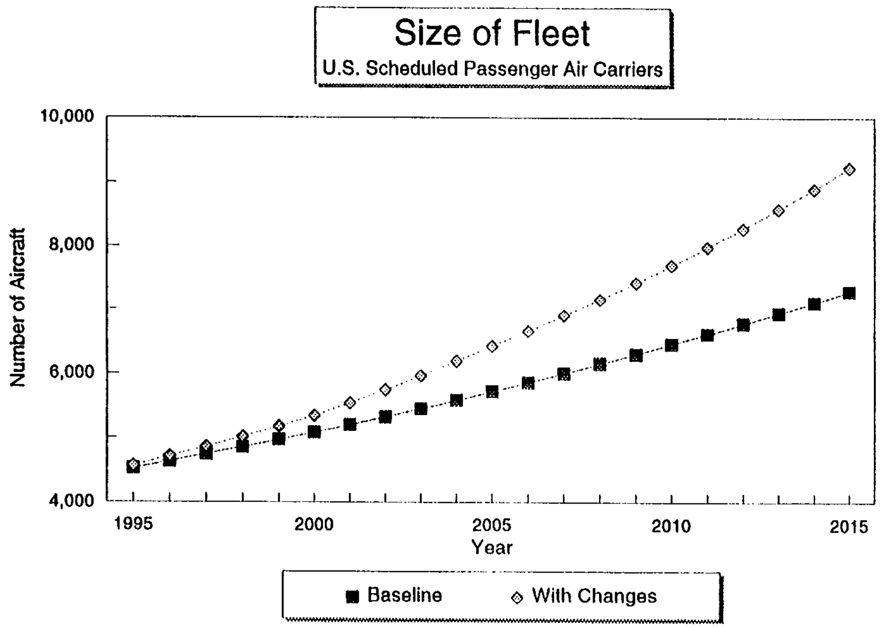

Year	Revised Number of A/C	Baseline Number of A/C
1995	4,566	4,528
1996	4,710	4,633
1997	4,860	4,740
1998	5,015	4,851
1999	5,176	4,965
2000	5,343	5,081
2001	5,540	5,201
2002	5,744	5,325
2003	5,958	5,451
2004	6,179	5,581
2005	6,411	5,715
2006	6,647	5,853
2007	6,892	5,994
2008	7,148	6,140
2009	7,414	6,289
2010	7,692	6,443
2011	7,975	6,601
2012	8,270	6,763
2013	8,577	6,930
2014	8,897	7,102
2015	9,229	7,279
Growth	3.58%	2.40%

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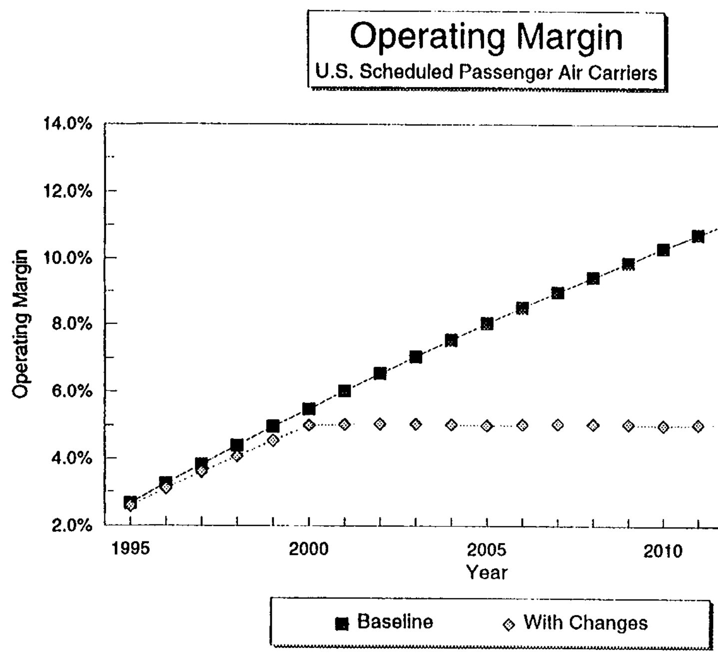

Year	Revised Operating Margin	Baseline Operating Margin
1995	2.6%	2.7%
1996	3.1%	3.3%
1997	3.6%	3.8%
1998	4.1%	4.4%
1999	4.5%	5.0%
2000	5.0%	5.5%
2001	5.0%	6.0%
2002	5.0%	6.5%
2003	5.0%	7.1%
2004	5.0%	7.5%
2005	5.0%	8.0%
2006	5.0%	8.5%
2007	5.0%	9.0%
2008	5.0%	9.4%
2009	5.0%	9.9%
2010	5.0%	10.3%
2011	5.0%	10.7%
2012	5.0%	11.1%
2013	5.0%	11.5%
2014	5.0%	11.9%
2015	5.0%	12.3%
Growth		

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Oil Price Shock

In an oil price shock scenario, the price of oil is assumed to be approximately twice as high by the year 2015 as it would have been in the baseline scenario. As a result, not only do energy prices increase at a faster pace, but real economic growth declines from 2.5 percent per year to 0 percent per year.

Because of the poor macroeconomic environment, the demand for passenger air travel declines dramatically relative to the baseline. The demand for aircraft also decreases because of the weak passenger demand and because energy and aircraft are complements. Consequently, both aircraft manufacturers and the airlines suffer under this scenario.

As shown in the second set of printouts, if the target operating margins of 5 percent apply, then fares will increase relative to the baseline and the decrease in passenger air travel and the derived demand for aircraft would be even greater. See the following spreadsheet printouts for details.

INDUSTRY ROLLUP Demand variables:	Annual Change (%)	Baseline Scenario
Fare yield, 1995 to 2000	-1.23	-1.23
Fare yield, 2001 to 2005	-1.23	-1.23
Fare yield, 2006 to 2010	-1.23	-1.23
Fare yield, 2011 to 2015	-1.23	-1.23
Income	0.00	2.50
Population	0.94	0.94
Unemployment rate	0.00	0.00
Supply variables:		
Price of labor	-1.60	-1.60
Price of energy	2.00	-1.60
Price of materials	0.00	0.00
Price of capital	-0.50	-0.50
Stage length	0.35	0.35
Load factor	0.15	0.15
Seats per A/C	0.75	0.75
Age of A/C	0.00	0.00
Percent jets*	0.0000000	0.0000000
Percent wide body*	0.0004909	0.0004909

*Note: not a percentage change, coefficients modified to reflect

	Target operating margins (%)
By year 2000	N/A
By year 2005	N/A
By year 2010	N/A
By year 2015	N/A

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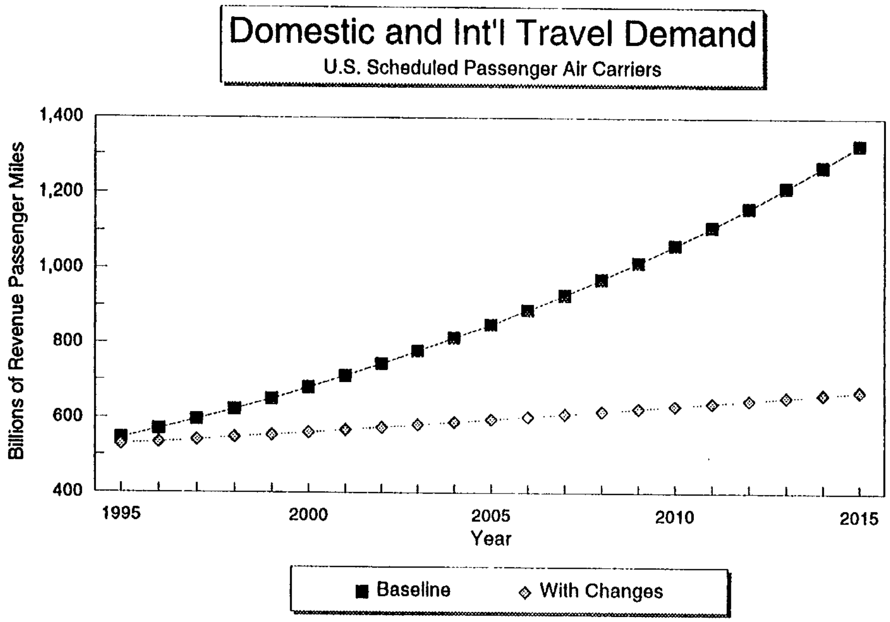

Year	Revised Total RPM (billions)	Baseline Total RPM (billions)
1995	526.901	544.267
1996	533.310	569.044
1997	539.798	594.950
1998	546.364	622.035
1999	553.010	650.352
2000	559.737	679.959
2001	566.546	710.914
2002	573.437	743.278
2003	580.413	777.115
2004	587.473	812.493
2005	594.619	849.481
2006	601.853	888.154
2007	609.174	928.586
2008	616.584	970.860
2009	624.084	1,015.058
2010	631.676	1,061.268
2011	639.360	1,109.581
2012	647.137	1,160.094
2013	655.009	1,212.907
2014	662.977	1,268.124
2015	671.041	1,325.854
Growth	1.22%	4.55%

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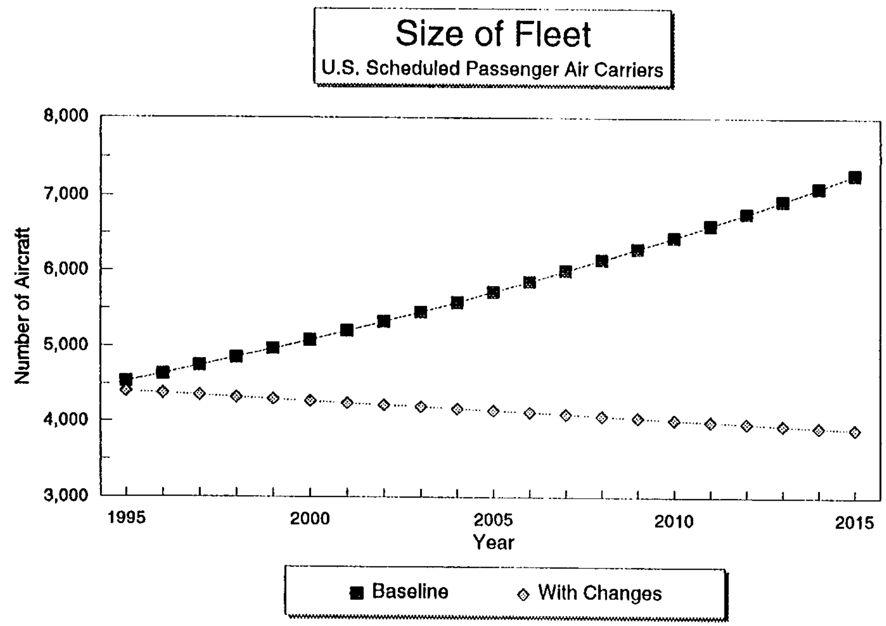

Year	Revised Number of A/C	Baseline Number of A/C
1995	4,399	4,528
1996	4,372	4,633
1997	4,345	4,740
1998	4,319	4,851
1999	4,292	4,965
2000	4,266	5,081
2001	4,240	5,201
2002	4,215	5,325
2003	4,189	5,451
2004	4,164	5,581
2005	4,139	5,715
2006	4,114	5,853
2007	4,089	5,994
2008	4,064	6,140
2009	4,039	6,289
2010	4,015	6,443
2011	3,991	6,601
2012	3,967	6,763
2013	3,943	6,930
2014	3,919	7,102
2015	3,895	7,279
Growth	-0.61%	2.40%

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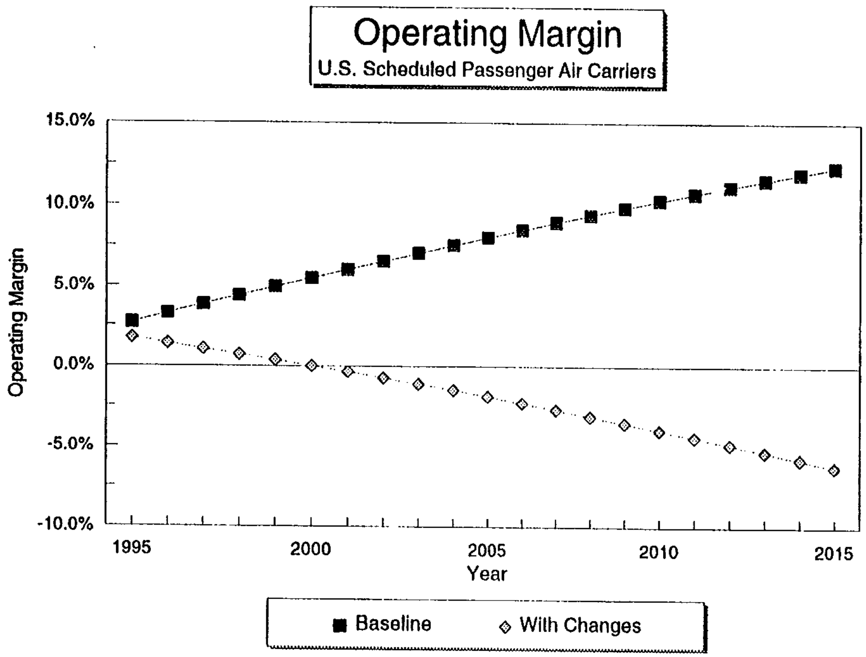

Year	Revised Operating Margin	Baseline Operating Margin
1995	1.7%	2.7%
1996	1.4%	3.3%
1997	1.1%	3.8%
1998	0.7%	4.4%
1999	0.4%	5.0%
2000	0.0%	5.5%
2001	-0.4%	6.0%
2002	-0.7%	6.5%
2003	-1.1%	7.1%
2004	-1.5%	7.5%
2005	-1.9%	8.0%
2006	-2.3%	8.5%
2007	-2.7%	9.0%
2008	-3.1%	9.4%
2009	-3.5%	9.9%
2010	-4.0%	10.3%
2011	-4.4%	10.7%
2012	-4.9%	11.1%
2013	-5.3%	11.5%
2014	-5.8%	11.9%
2015	-6.3%	12.3%
Growth		

OILSHOCK.WK4

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INDUSTRY ROLLUP	Annual	Baseline
Demand variables:	Change (%)	Scenario
Fare yield, 1995 to 2000	-0.28	-1.23
Fare yield, 2001 to 2005	-0.81	-1.23
Fare yield, 2006 to 2010	-0.78	-1.23
Fare yield, 2011 to 2015	-0.75	-1.23
Income	0.00	2.50
Population	0.94	0.94
Unemployment rate	0.00	0.00
Supply variables:		
Price of labor	-1.60	-1.60
Price of energy	2.00	-1.60
Price of materials	0.00	0.00
Price of capital	-0.50	-0.50
Stage length	0.35	0.35
Load factor	0.15	0.15
Seats per A/C	0.75	0.75
Age of A/C	0.00	0.00
Percent jets*	0.0000000	0.0000000
Percent wide body*	0.0004909	0.0004909

*Note: not a percentage change, coefficients modified to reflect

	Target operating margins (%)
By year 2000	5.00
By year 2005	5.00
By year 2010	5.00
By year 2015	5.00

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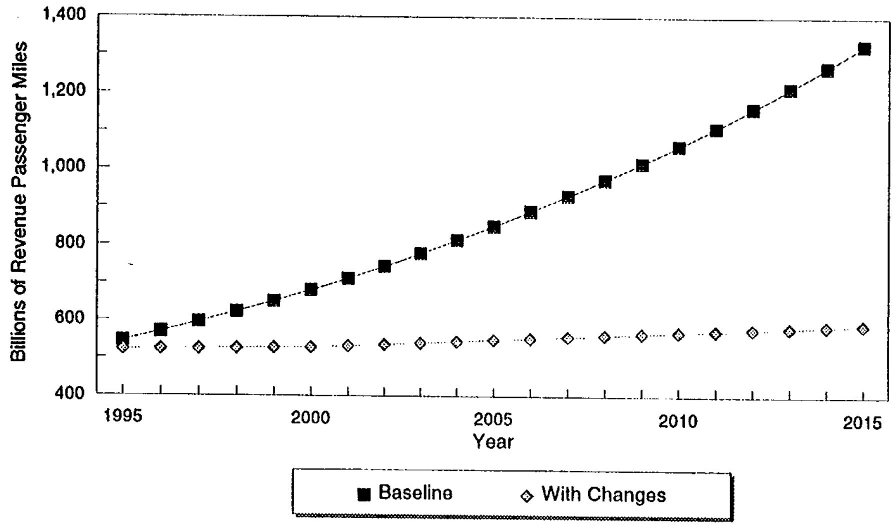
Domestic and Int'l Travel Demand

U.S. Scheduled Passenger Air Carriers



Year	Revised Total RPM (billions)	Baseline Total RPM (billions)
1995	521.580	544.267
1996	522.594	569.044
1997	523.609	594.950
1998	524.627	622.035
1999	525.646	650.352
2000	526.668	679.959
2001	530.730	710.914
2002	534.823	743.278
2003	538.948	777.115
2004	543.105	812.493
2005	547.294	849.481
2006	551.341	888.154
2007	555.417	928.586
2008	559.524	970.860
2009	563.661	1,015.058
2010	567.828	1,061.268
2011	571.846	1,109.581
2012	575.892	1,160.094
2013	579.967	1,212.907
2014	584.071	1,268.124
2015	588.204	1,325.854
Growth	0.60%	4.55%

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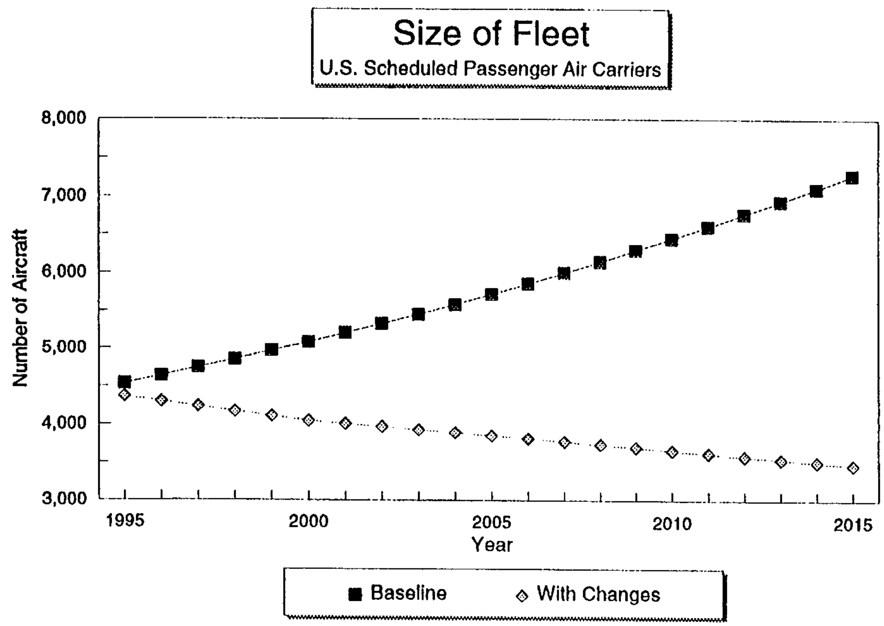

Year	Revised Number of A/C	Baseline Number of A/C
1995	4,359	4,528
1996	4,294	4,633
1997	4,229	4,740
1998	4,165	4,851
1999	4,103	4,965
2000	4,041	5,081
2001	4,000	5,201
2002	3,960	5,325
2003	3,921	5,451
2004	3,882	5,581
2005	3,843	5,715
2006	3,804	5,853
2007	3,765	5,994
2008	3,726	6,140
2009	3,688	6,289
2010	3,650	6,443
2011	3,611	6,601
2012	3,573	6,763
2013	3,536	6,930
2014	3,498	7,102
2015	3,461	7,279
Growth	-1.15%	2.40%

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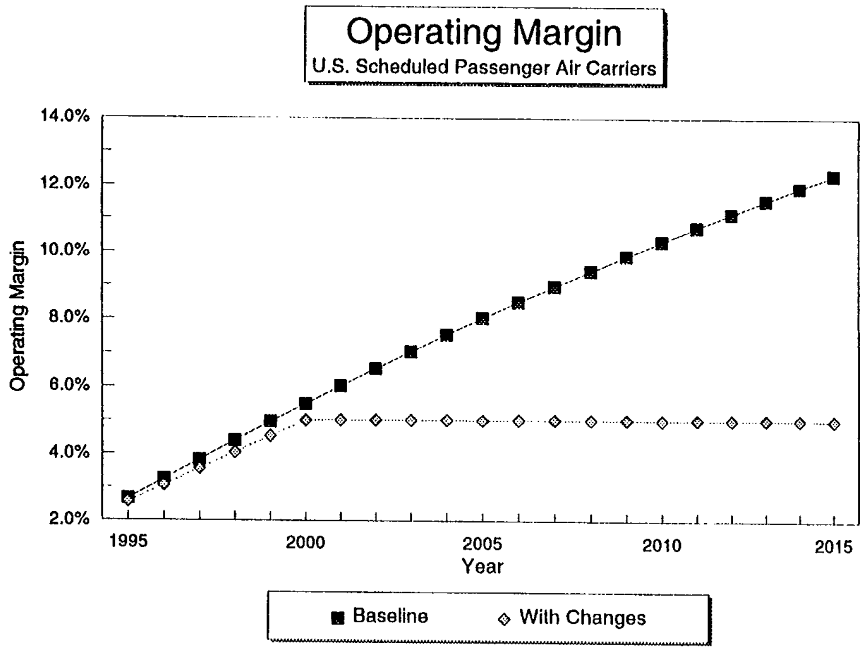

Year	Revised Operating Margin	Baseline Operating Margin
1995	2.6%	2.7%
1996	3.1%	3.3%
1997	3.6%	3.8%
1998	4.0%	4.4%
1999	4.5%	5.0%
2000	5.0%	5.5%
2001	5.0%	6.0%
2002	5.0%	6.5%
2003	5.0%	7.1%
2004	5.0%	7.5%
2005	5.0%	8.0%
2006	5.0%	8.5%
2007	5.0%	9.0%
2008	5.0%	9.4%
2009	5.0%	9.9%
2010	5.0%	10.3%
2011	5.0%	10.7%
2012	5.0%	11.1%
2013	5.0%	11.5%
2014	5.0%	11.9%
2015	5.0%	12.3%
Growth		

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AIRLINE FARE WAR

In an airline fare war scenario, the airlines are assumed to cut fares more rapidly than in the baseline. While this stimulates the demand for passenger air travel and the derived demand for aircraft, airline operating margins suffer. This scenario is probably self-limiting because negative operating margins would cause many firms to exit the industry and certainly would constrain the availability of credit with which to finance the needed increases in fleets and networks.

The second set of printouts holds all supply and demand variables – except fare yields – at the baseline levels and estimates the changes in fare yields required to achieve 5 percent operating profit margins in each of the four target years. See the following spreadsheet printouts for details.

INDUSTRY ROLLUP	Annual	Baseline
Demand variables:	Change (%)	Scenario
Fare yield, 1995 to 2000	-2.00	-1.23
Fare yield, 2001 to 2005	-2.00	-1.23
Fare yield, 2006 to 2010	-2.00	-1.23
Fare yield, 2011 to 2015	-2.00	-1.23
Income	2.50	2.50
Population	0.94	0.94
Unemployment rate	0.00	0.00
Supply variables:		
Price of labor	-1.60	-1.60
Price of energy	-1.60	-1.60
Price of materials	0.00	0.00
Price of capital	-0.50	-0.50
Stage length	0.35	0.35
Load factor	0.15	0.15
Seats per A/C	0.75	0.75
Age of A/C	0.00	0.00
Percent jets*	0.0000000	0.0000000
Percent wide body*	0.0004909	0.0004909

*Note: not a percentage change, coefficients modified to reflect

	Target operating margins (%)
By year 2000	N/A
By year 2005	N/A
By year 2010	N/A
By year 2015	N/A

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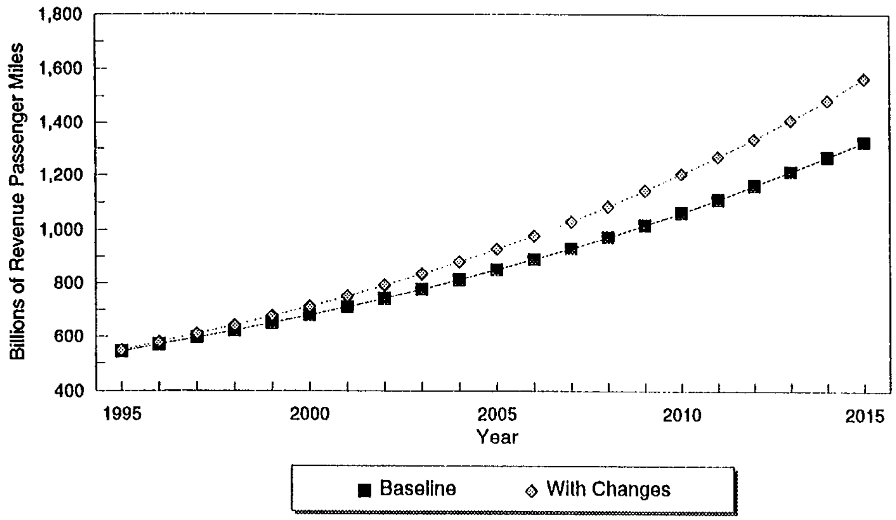
Domestic and Int'l Travel Demand

U.S. Scheduled Passenger Air Carriers



Year	Revised Total RPM (billions)	Baseline Total RPM (billions)
1995	548.558	544.267
1996	578.052	569.044
1997	609.133	594.950
1998	641.884	622.035
1999	676.397	650.352
2000	712.765	679.959
2001	751.088	710.914
2002	791.472	743.278
2003	834.027	777.115
2004	878.871	812.493
2005	926.125	849.481
2006	975.920	888.154
2007	1,028.393	928.586
2008	1,083.687	970.860
2009	1,141.954	1,015.058
2010	1,203.354	1,061.268
2011	1,268.055	1,109.581
2012	1,336.235	1,160.094
2013	1,408.080	1,212.907
2014	1,483.789	1,268.124
2015	1,563.568	1,325.854
Growth	5.38%	4.55%

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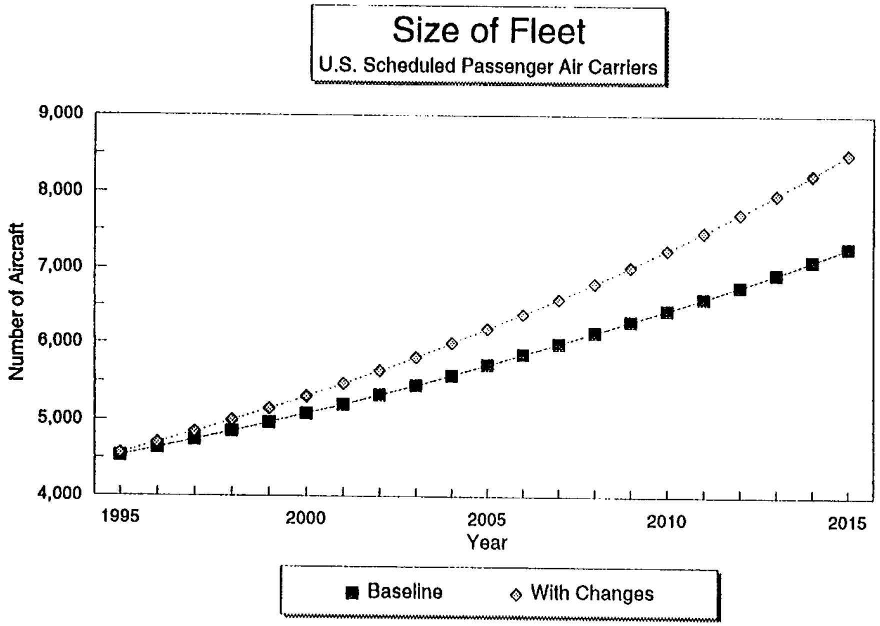

Year	Revised Number of A/C	Baseline Number of A/C
1995	4,560	4,528
1996	4,699	4,633
1997	4,843	4,740
1998	4,991	4,851
1999	5,145	4,965
2000	5,305	5,081
2001	5,469	5,201
2002	5,640	5,325
2003	5,817	5,451
2004	5,999	5,581
2005	6,189	5,715
2006	6,385	5,853
2007	6,588	5,994
2008	6,798	6,140
2009	7,016	6,289
2010	7,242	6,443
2011	7,476	6,601
2012	7,718	6,763
2013	7,970	6,930
2014	8,230	7,102
2015	8,500	7,279
Growth	3.16%	2.40%

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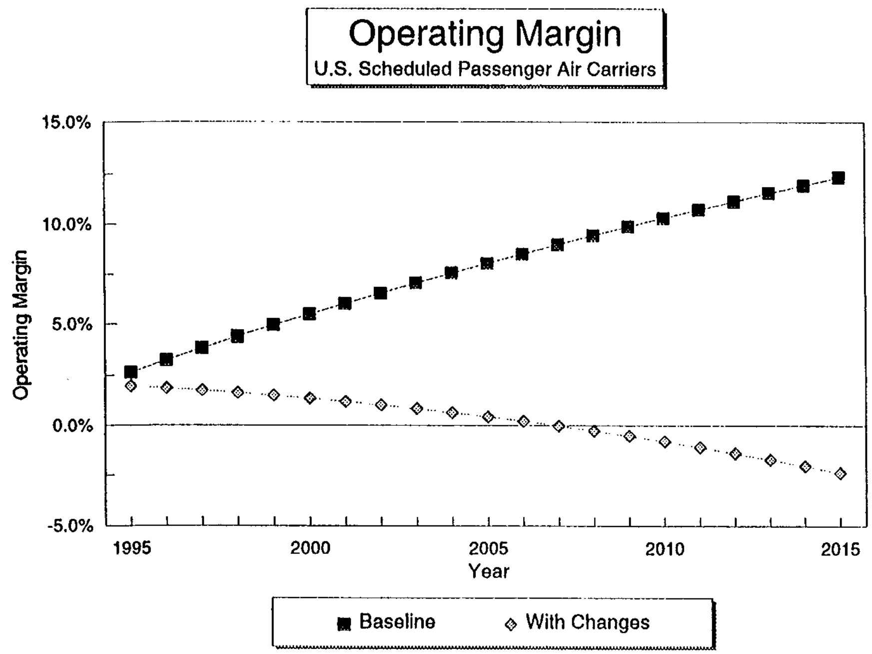

Year	Revised Operating Margin	Baseline Operating Margin
1995	2.0%	2.7%
1996	1.9%	3.3%
1997	1.8%	3.8%
1998	1.6%	4.4%
1999	1.5%	5.0%
2000	1.3%	5.5%
2001	1.2%	6.0%
2002	1.0%	6.5%
2003	0.8%	7.1%
2004	0.6%	7.5%
2005	0.4%	8.0%
2006	0.2%	8.5%
2007	-0.0%	9.0%
2008	-0.3%	9.4%
2009	-0.5%	9.9%
2010	-0.8%	10.3%
2011	-1.1%	10.7%
2012	-1.4%	11.1%
2013	-1.7%	11.5%
2014	-2.0%	11.9%
2015	-2.4%	12.3%
Growth		

FAREWAR.WK4

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INDUSTRY ROLLUP	Annual	Baseline
Demand variables:	Change (%)	Scenario
Fare yield, 1995 to 2000	-1.32	-1.23
Fare yield, 2001 to 2005	-1.81	-1.23
Fare yield, 2006 to 2010	-1.75	-1.23
Fare yield, 2011 to 2015	-1.69	-1.23
Income	2.50	2.50
Population	0.94	0.94
Unemployment rate	0.00	0.00
Supply variables:		
Price of labor	-1.60	-1.60
Price of energy	-1.60	-1.60
Price of materials	0.00	0.00
Price of capital	-0.50	-0.50
Stage length	0.35	0.35
Load factor	0.15	0.15
Seats per A/C	0.75	0.75
Age of A/C	0.00	0.00
Percent jets*	0.0000000	0.0000000
Percent wide body*	0.0004909	0.0004909

*Note: not a percentage change, coefficients modified to reflect

	Target operating margins (%)
By year 2000	5.00
By year 2005	5.00
By year 2010	5.00
By year 2015	5.00

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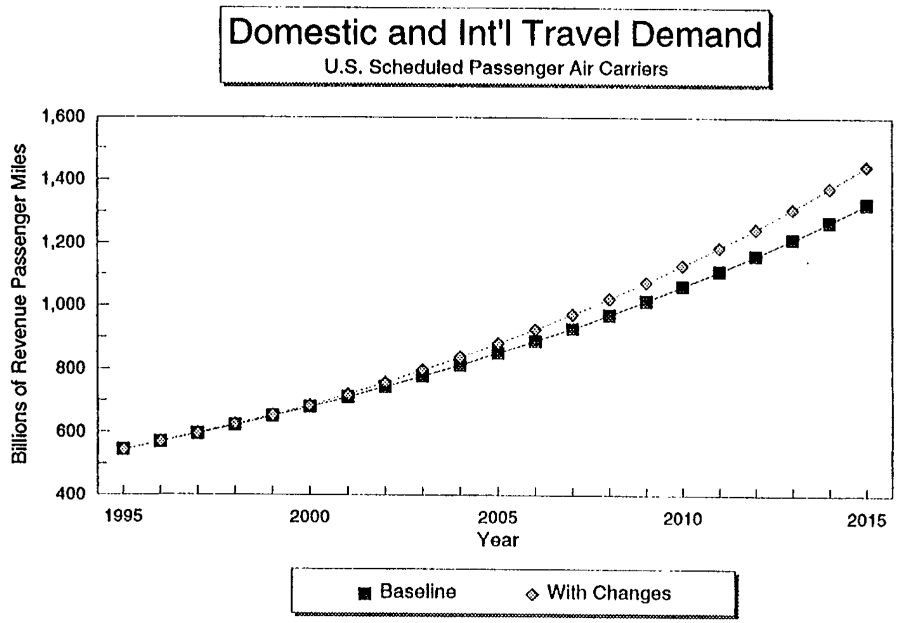

Year	Revised Total RPM (billions)	Baseline Total RPM (billions)
1995	544.790	544.267
1996	570.139	569.044
1997	596.667	594.950
1998	624.429	622.035
1999	653.483	650.352
2000	683.889	679.959
2001	719.280	710.914
2002	756.502	743.278
2003	795.651	777.115
2004	836.825	812.493
2005	880.131	849.481
2006	925.119	888.154
2007	972.407	928.586
2008	1,022.112	970.860
2009	1,074.358	1,015.058
2010	1,129.275	1,061.268
2011	1,186.304	1,109.581
2012	1,246.214	1,160.094
2013	1,309.149	1,212.907
2014	1,375.263	1,268.124
2015	1,444.715	1,325.854
Growth	5.00%	4.55%

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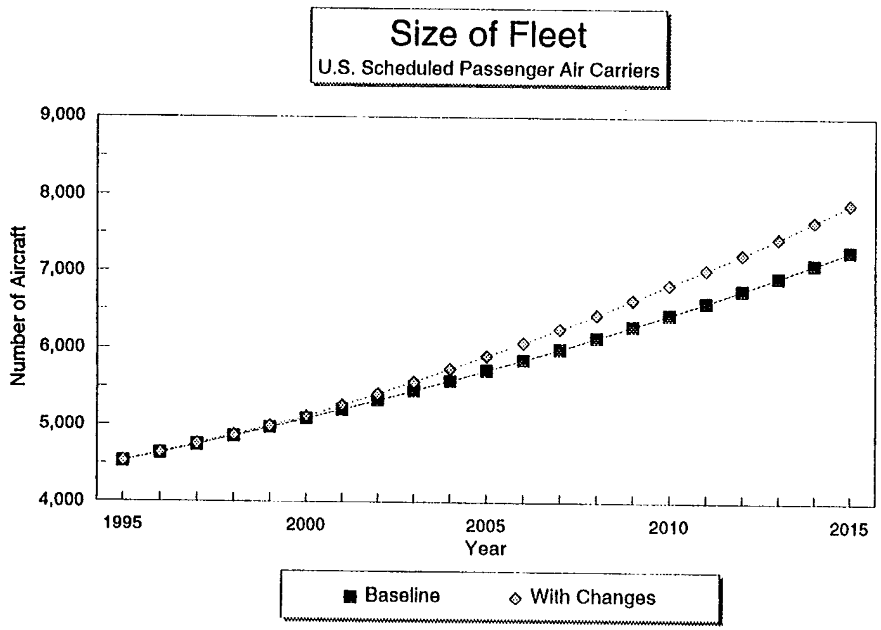

Year	Revised Number of A/C	Baseline Number of A/C
1995	4,532	4,528
1996	4,641	4,633
1997	4,753	4,740
1998	4,868	4,851
1999	4,986	4,965
2000	5,108	5,081
2001	5,257	5,201
2002	5,411	5,325
2003	5,570	5,451
2004	5,735	5,581
2005	5,905	5,715
2006	6,077	5,853
2007	6,255	5,994
2008	6,439	6,140
2009	6,629	6,289
2010	6,826	6,443
2011	7,025	6,601
2012	7,230	6,763
2013	7,443	6,930
2014	7,663	7,102
2015	7,890	7,279
Growth	2.81%	2.40%

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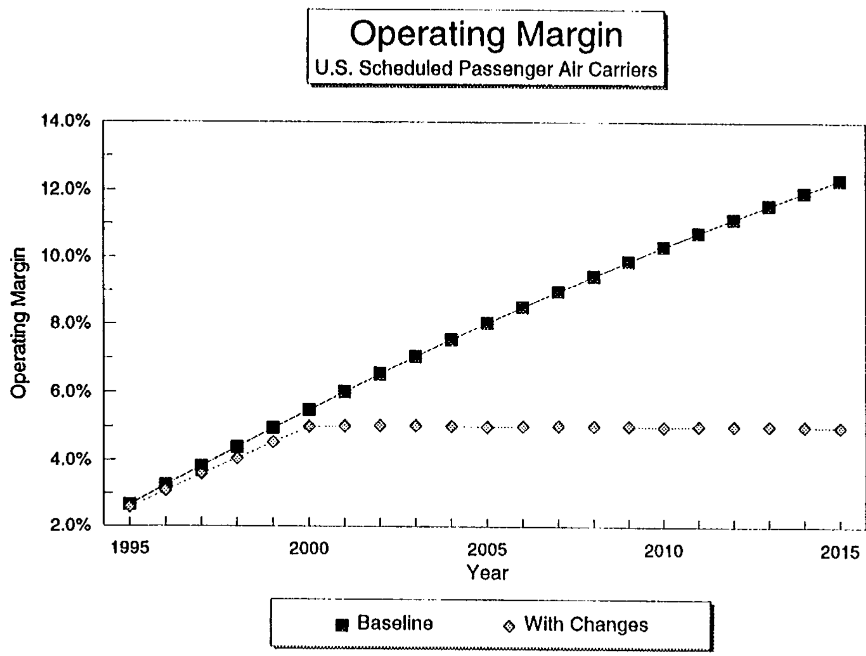

Year	Revised Operating Margin	Baseline Operating Margin
1995	2.6%	2.7%
1996	3.1%	3.3%
1997	3.6%	3.8%
1998	4.1%	4.4%
1999	4.5%	5.0%
2000	5.0%	5.5%
2001	5.0%	6.0%
2002	5.0%	6.5%
2003	5.0%	7.1%
2004	5.0%	7.5%
2005	5.0%	8.0%
2006	5.0%	8.5%
2007	5.0%	9.0%
2008	5.0%	9.4%
2009	5.0%	9.9%
2010	5.0%	10.3%
2011	5.0%	10.7%
2012	5.0%	11.1%
2013	5.0%	11.5%
2014	5.0%	11.9%
2015	5.0%	12.3%
Growth		

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13. ABSTRACT *(Maximum 200 words)*

To meet its objective of assisting U.S. industry with the technological challenges of the future, NASA must identify research areas that have the greatest potential for improving the operation of the air transportation system. Therefore, NASA seeks to develop the ability to evaluate the potential impact of various advanced technologies. By thoroughly understanding the economic impact of advanced aviation technologies, and by evaluating how those new technologies would be used within the integrated aviation system, NASA aims to balance its aeronautical research program and help speed the introduction of high-leverage technologies. To accomplish this, NASA is building an Aviation System Analysis Capability (ASAC).

The ASAC is envisioned primarily as a process for understanding and evaluating the impact of advanced aviation technologies on the U.S. economy. ASAC consists of a diverse collection of models, data bases, analysts, and individuals from the public and private sectors brought together to work on issues of common interest to organizations within the aviation community. ASAC also will be a resource available to those same organizations, to perform analyses; provide information; and assist scientists, engineers, analysts, and program managers in their daily work.

The ASAC differs from previous NASA modeling efforts in that the economic behavior of buyers and sellers in the air transportation and aviation industries is central to its conception. To link the economics of flight with the technology of flight, ASAC requires a parametrically based model that links airline operations and investments in aircraft wih aircraft characteristics. That model also must provide a mechanism for incorporating air travel demand and profitability factors into the airlines' investment decisions. Finally, the model must be flexible and capable of being incorporated into a wide-ranging suite of economic and technical models that are envisioned for ASAC. This report describes a prototype air carrier investment model that meets these requirements.

14. SUBJECT TERMS

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